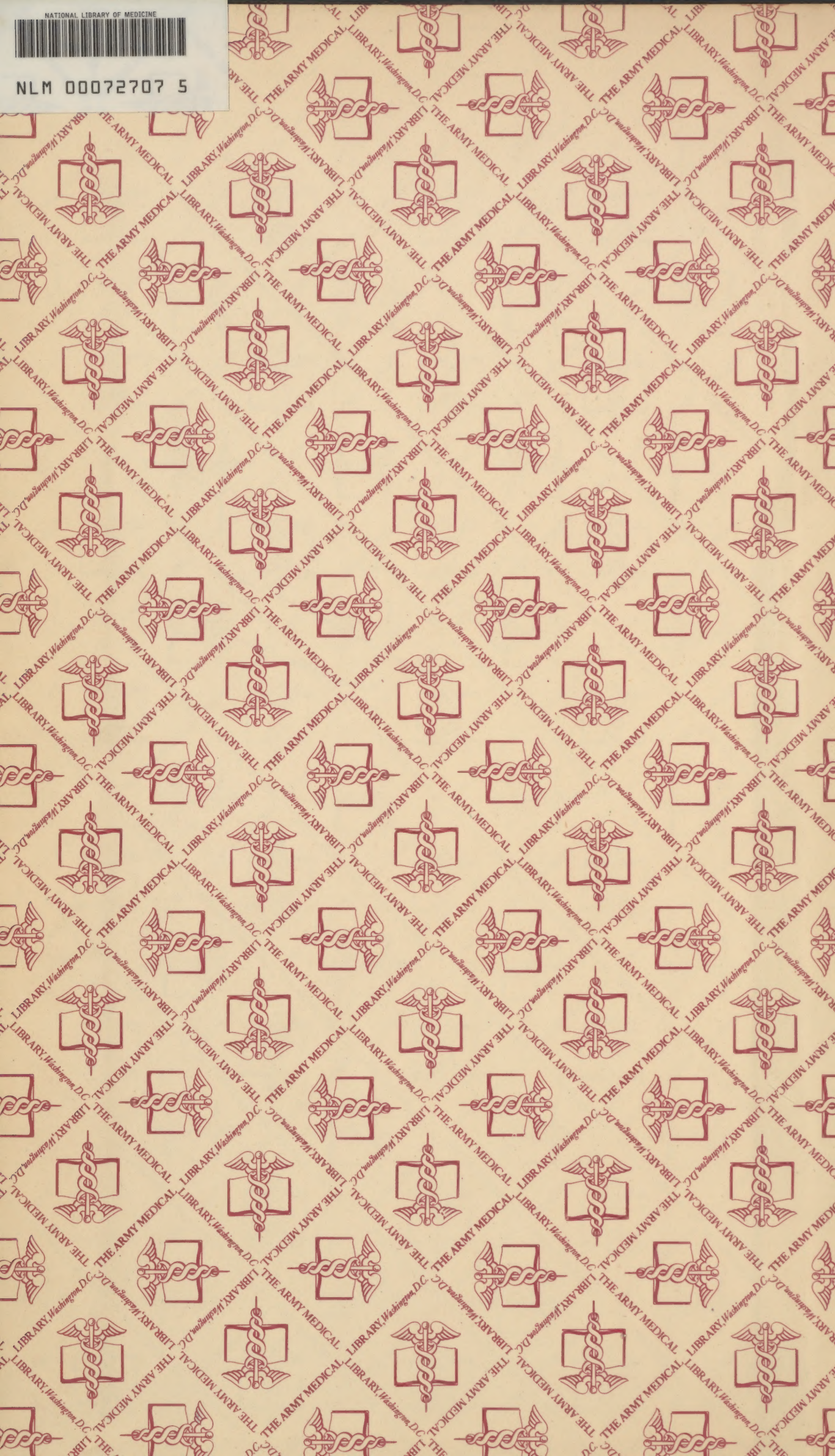
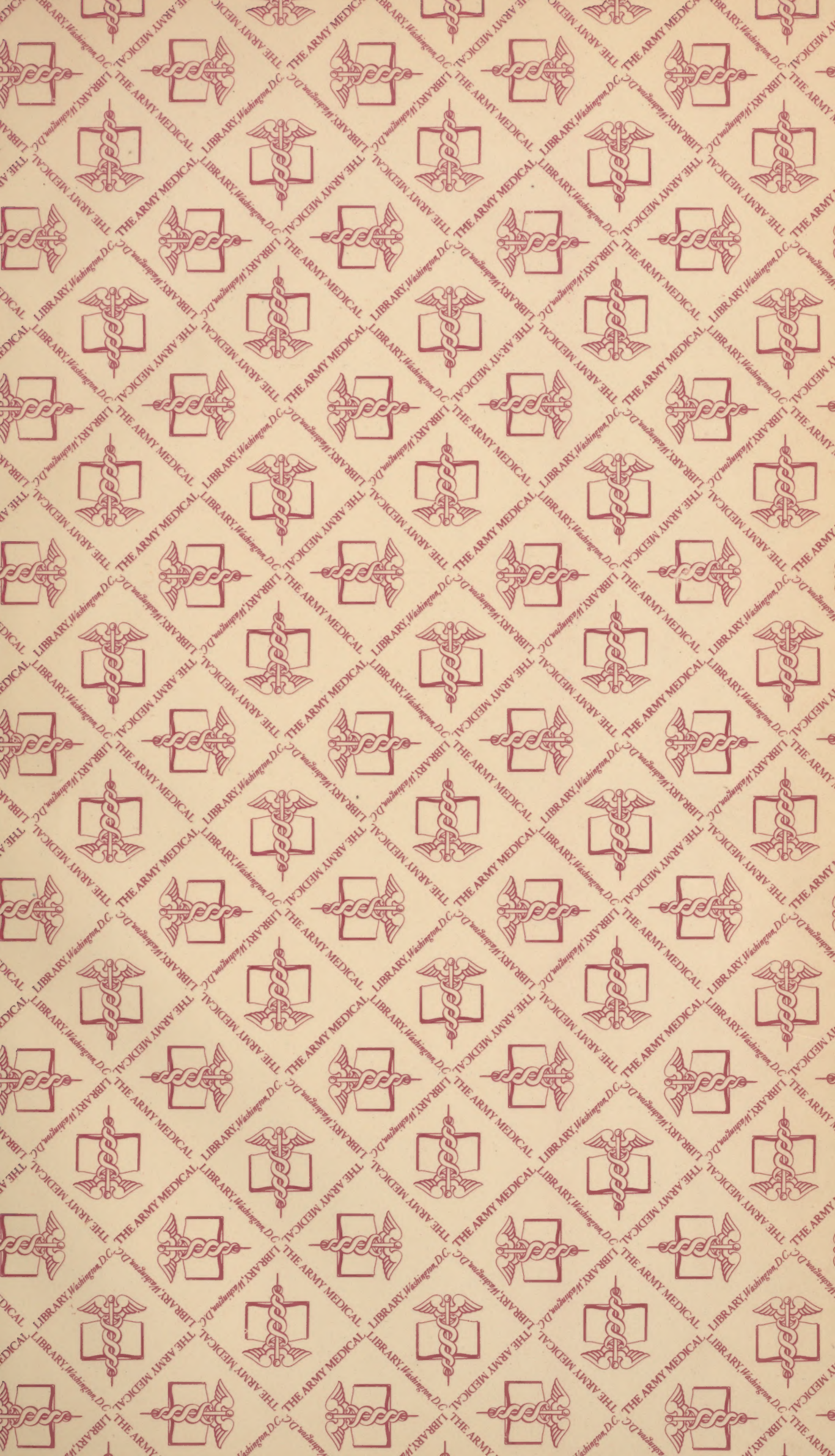




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CHAPTER VI.

Osteotomy by means of marrow nails.

A. General remarks.

Osteotomy means, strictly speaking, a severing of the bone. It is most frequently performed in cases of poorly healed bone fractures. The operative correction of a congenital curvature falls under the same heading. But also the operative treatment of a bone fracture is in most cases called osteotomy. Accordingly, all these interventions are included in this chapter, during which the bone is exposed, severed, and re-joined, or if it was severed before, such as in case of poorly fixed fractures, or pseudarthroses, it is exposed and re-joined.

For re-joining, we have many different contrivances available, such as wires, screws, plates, etc. but none of them guarantees a really stable union. In any case additional fixation is necessary by means of a plaster cast or splint, or even the use of the extension method in some cases. The insufficient mechanical stability of the osteosynthesis obtained by the use of these contrivances arises from two causes:

These contrivances have been constructed too weak so that they cannot stand the strain they are exposed to, and their fastening becomes loosened by the resorption of the bones. The strain exerted by osteosynthesis is equal to that of the normal bone, as described in detail in chapter III. It is produced by the muscular strength and amounts to enormous figures, since, when a bone is severed, the whole cross-section of the musculature works in the same direction, so that, in this case, the usual antagonists, flexors and extensors, adductors and abductors cooperate. For this reason, the extension forces and the pressing forces will amount to several hundred kilograms. The form of the strain tends to produce angulation. With the osteosynthesis, it manifests itself as an angulation at the place of osteotomy.

For this reason it is natural to use marrow nails also during osteotomy, since it is the marrow nail alone, which is capable of resisting these forces without any additional plaster cast or traction, in order to obtain thus a really "stable osteosynthesis".

The author accordingly has some osteotomies even among his first marrow nailings. If the method is used in this form, however, the great advantages of marrow nailing for simple fractures as described in the preceding chapter are not all present to the same extent. This results from the fact that the injury of the bone is exposed. This always involves a considerable increase of the danger of infection, damage to the periosteum, as well as other dangers and disadvantages (see chapter IV). It will be demonstrated in particular that these dangers are less imminent in case of application of marrow nails than in case of the methods used previously though the indications for intervention by means of osteotomy must not be less strict than before.

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Indications for osteotomy.

It is difficult to give exact directions for indications for osteotomy. In the first place, much depends on the skill and the experience of the individual surgeon, for osteotomy is one of the most difficult operations. This also applies if marrow nails are used. Just in this case, many technical details and special maneuvers must be observed.

There is a great difference concerning the tendency for treating fractures operatively in the various countries. It is greatest in the United States, where ALBEE's excellent methods have found many adherents. But even in Europe there are surgeons who treat up to 30 % of all fractures operatively. In Germany, one is much reserved, though, under the influence of F. KOENIG and MATTI, one has given up the point of view that only those fractures should be treated operatively with which the conservative methods have failed. Chiefly owing to KOENIG's merit, exact indications have been established, to the effect that only those fractures should be treated operatively which, when treated by conservative methods, yield poor results, as shown by experience.

One must consider again and again that in case of operative exposure of the fracture, the bone necessarily will not heal so well as without it, because of damage to the regenerating bone, chiefly by injury of the periosteum and because of the danger of infection. Both involve a considerable delay, as demonstrated in chapters III and IV. Statistics also show that operated fractures need 2 - 3 times as much time for healing, which means a correspondingly longer fixation and injury to the joints. For this reason operation is suitable only if other, greater disadvantages are avoided or removed by it. Not even the generous use of sulfonamides, can decisively decrease the danger of infection, but penicillin does effect it. We wish to demonstrate later that the use of marrow nails may also considerably decrease the disturbances of the regeneration of the bones resulting from damage to the periosteum. Herein lies the greatest advantage in the use of marrow nails during osteotomy, though the other advantages of marrow nailing exist as in case of simple fractures. These are:

1. Absolute fixation of the fracture, and thus ideal mechanico-biological conditions for the transformation of the regenerated tissue to osseous callus (see chapter III). It is both a good prophylaxis and therapy of infection.
2. Absolutely "stable osteosynthesis". Thus, the nail is not only a substitute for the contrivances used previously (screws, plates, etc.), but the realization of an entirely new principle with all the immense advantages of early motion for the preservation of muscles, joints and circulation of the injured limbs, for the formation of callus, and the general condition of the body, and for the guarantee of the anatomical result of the operation.

The greatest advantage, however, is the fact, as mentioned above, that we may arrive through use of marrow nails, at an entirely new principle of osteosynthesis, that of the greatest possible conservation of the periosteum as far as the damage to the regenerating bone is concerned.

This requires an entirely new technique. It is emphasized on purpose that we may arrive at this principle: Of course, one can as well perform marrow nailing osteotomy according to the former technique with extensive separation of the periosteum from the bone and even severing of the connection with the soft parts. But in that case, one sets aside this important advantage. This separation is inevitable for the fixation making use of LANE's plates or a wire splint. If we use marrow nails, however, we can desist from this old principle of VON LANGENBECK's subperiosteal operation. It has been shown in chapter III, that the periosteum has the principal share in the regeneration of the bones, and BARTH's and the author's experiments have been mentioned, according to which periosteal osteogenesis will occur to its full extent only if the periosteum closely adheres to the bone. So it is of the utmost importance for the formation of callus that the periosteum is not detached at all. In addition, the periosteum forms the most important blood supply of the outer compacta layers of the bone. For this reason, detaching the periosteum involves a serious damage to the blood supply of the bone and thus to its power of resistance against infection. This is certainly one of the reasons why osteotomies are so easily infected. Lastly, detaching the periosteum involves a considerable increase of the injured area, which increases the danger of infection as well.

As mentioned in chapter III, the necrotic or necrobiotic bone is truly a strong stimulus for the regeneration of the bone. This is, according to LEXER, the advantage of the subperiosteal operation; though, during this operation the periosteum must be detached very cautiously and together with the surrounding muscles, which contain the most important vessels for the periosteum. The nail in its marrow cavity, however, can produce a stimulation at least equally strong without the periosteum being detached, as the author was in a position to show (see chapter III). As mentioned before, the necrobiotic bone can only be effective if the periosteum closely adheres to the bone. If this is not the case, the interstice will be filled with coagulated blood. The osteogenic cells first have to force their way through it and reach the bone, according to BARTH, only with difficulty or too late. The most unsatisfactory kind of osteotomy doubtlessly is the transperiosteal one, i.e. exposure of the bone covered with periosteum from the soft parts with subsequent detachment of the periosteum from the bone, for then, the periosteum and the bone are deprived of the greater part of the supplying vessels.

With the use of marrow nails, it is possible in most cases to leave intact to a large extent the connection of the periosteum with both the bone and the surrounding soft parts (see illustration 129).

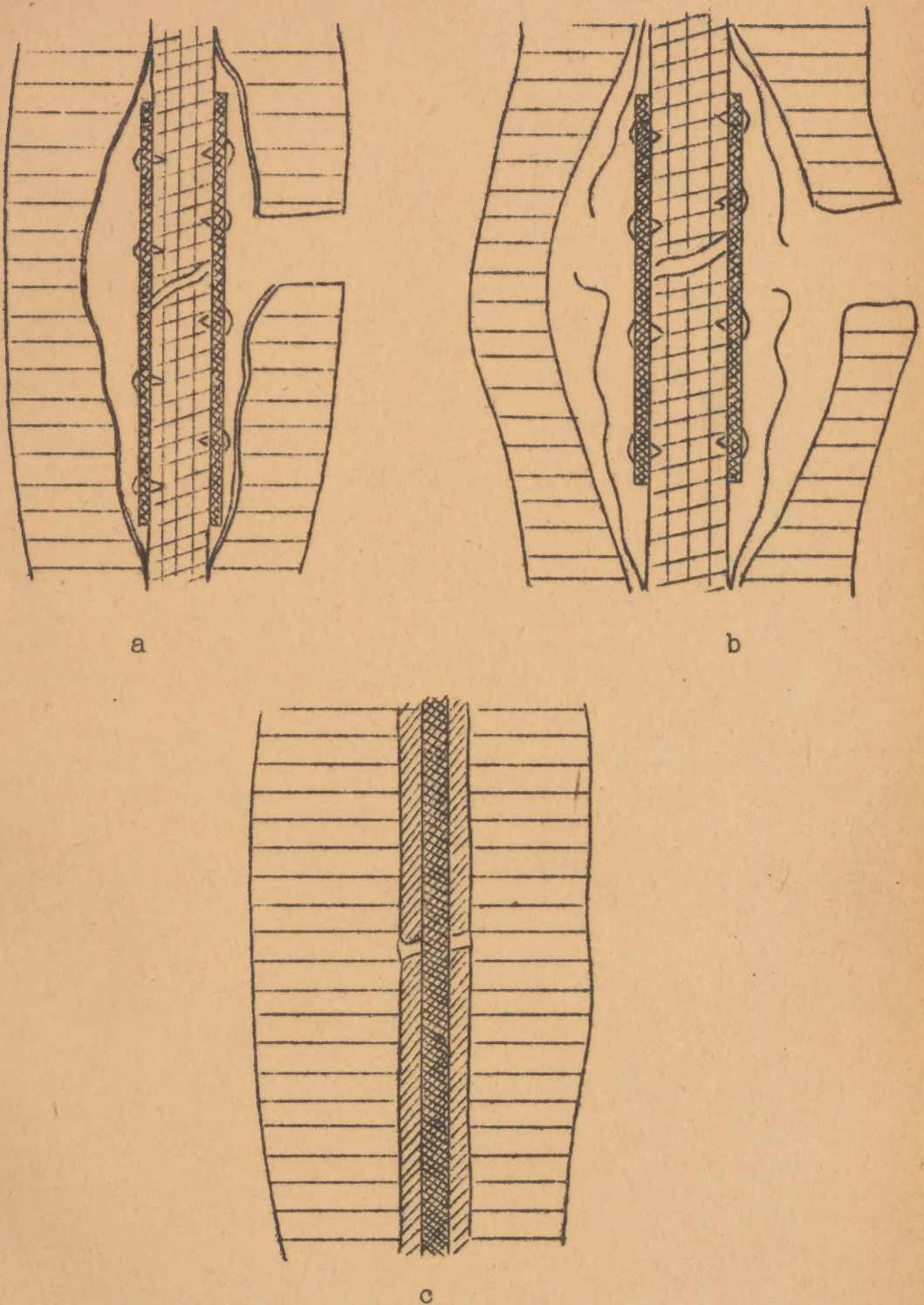


Illustration 129.

Scheme of the osteosynthesis;

- a) subperiosteal osteotomy according to VON LANGENBECK - detachment of the periosteum from the bone
- b) transperiosteal operation - detachment of the periosteum from the bone and the surrounding soft parts
- c) marrow nail osteosynthesis according to KUENTSCHER - leaving intact the connection of the periosteum with both the bone and the surrounding area.

This requires a special way of proceeding during osteosynthesis, which is quite different from the usual procedure. Operations have been performed in this way before, for instance during the oblique subtrochanteric osteotomy according to HOFFA, but they were limited to occasional exceptional cases. They were always osteotomies and never osteosyntheses. The HOFFA osteotomy rather renounces synthesis, and the bone ends are held together by the surrounding soft parts. But the connection of the periosteum with the soft parts and the bone is left absolutely intact, since only a small incision of the skin is made, into which the chisel is introduced and pushed through the soft parts to the periosteum. Then, periosteum and bone are severed together at the same time. On principle marrow nail osteotomy is performed in a similar way, only it is followed by marrow nail synthesis. This method is applicable to all long tube bones. Of course, the small incision as made during HOFFA's osteotomy will do only in a very few cases, though the incision of the skin is in most cases considerably smaller than with the former osteosynthesis, for the site of osteotomy need not be exposed in all directions and over a large area as for instance in the case of application of Lane's plates. Nor is it necessary to remove the callus which may happen to exist, which is required when Lane's plates are used. It is sufficient to sever the fragments; the masses of callus are left intact, for the periosteum usually adheres particularly closely to them and, because of the numerous cracks and fissures of the callus masses, the periosteum can hardly be detached, at least half will be undamaged. The callus masses, being valuable building material, form the new callus on the spot. We wish to illustrate this by 2 examples:

Two years ago, patient S. sustained a gunshot fracture of the left thigh at the border of the upper third, which healed in marked adduction, with 5 centimeters shortening. There was still a fistula when the nail was applied (see illustration 130c). A 5 cm. long incision of the skin was made on the lateral side of the thigh. At that place, the tip of the proximal fragment could be observed under the skin. After the incision it was observed that the tip was still covered by a layer of muscles $\frac{1}{2}$ - 1 cm. thick. These muscles were left completely intact above the proximal end. Starting directly at the tip, the muscles were bluntly split by two raspatories distally for about 3 cm. The marrow cavity of the proximal fragment could now be opened with an awl, which was easily performed. Then, a 3 cm. broad chisel was obliquely applied in the direction of the inner edge of the proximal fragment, as shown in illustration 130 b. Then, the two fragments were separated by one blow and the marrow cavity of the distal fragment was drilled open in the same way, as the proximal one. The marrow nail was now driven in as described later in this chapter. The periosteum was everywhere left practically intact during this operation. Its connection with the bone and the soft parts was broken nowhere. Not the slightest piece of callus was removed. After the operation, the masses of callus lay almost as close to each other as in case of a month old fracture. The shortening was completely corrected. The operation lasted 12 minutes.

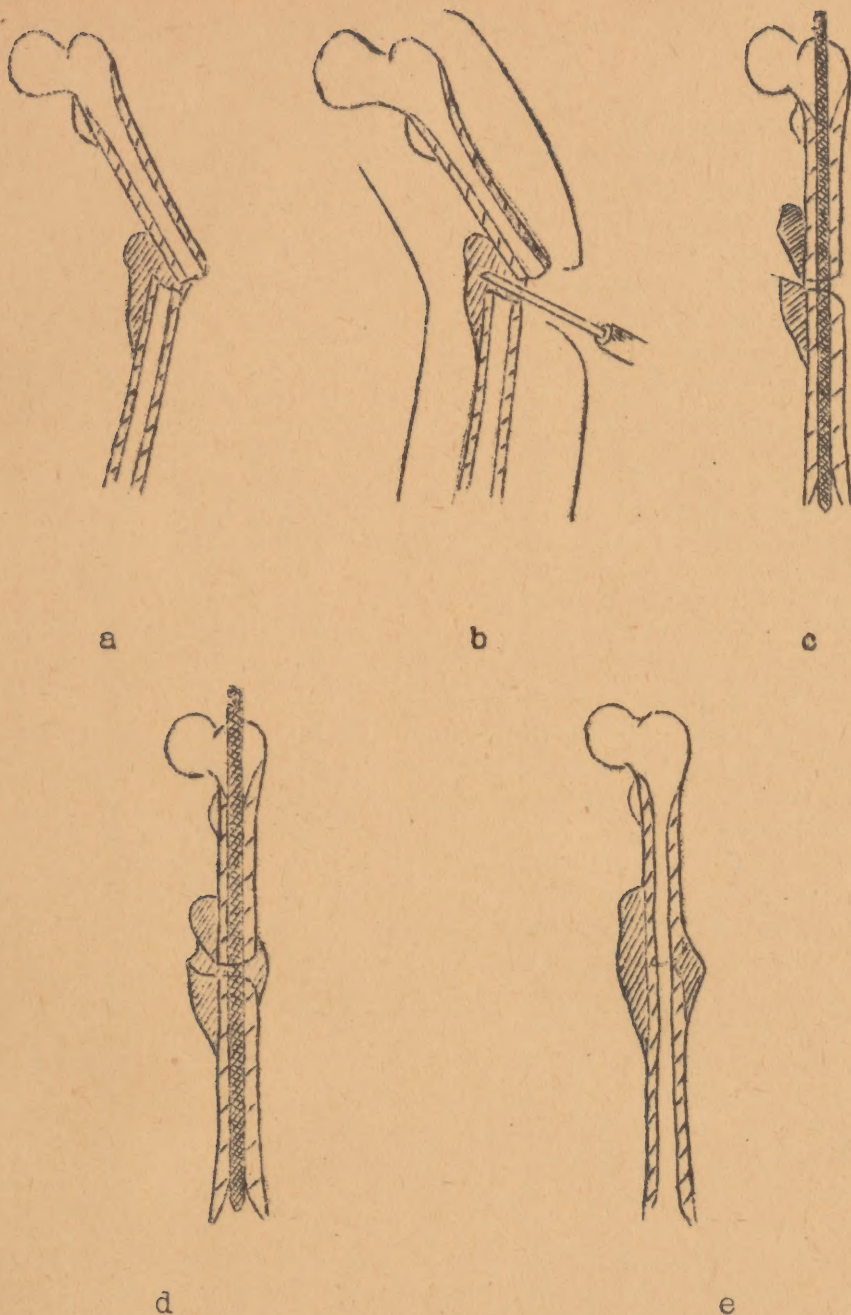


Illustration 130.

- a) Patient S. 2 year old healed gunshot fracture of the femur with fistula, marked angulation of the axis and 5 cm. shortening.
- b) Diagram of the incision of the skin and of the direction of the severing of the callus with a chisel. No piece of callus was removed, the periosteum everywhere remains in connection with the bone and the surrounding muscles.
- c) After marrow nailing immediately after the operation (with drainage).
- d) After 10 weeks.
- e) After removal of the nail, 16 weeks after the operation.

If a 8 cm. long Lane's plate had been applied, a considerable part of the periosteum and callus would have had to be removed, as is shown schematically in illustration 131.

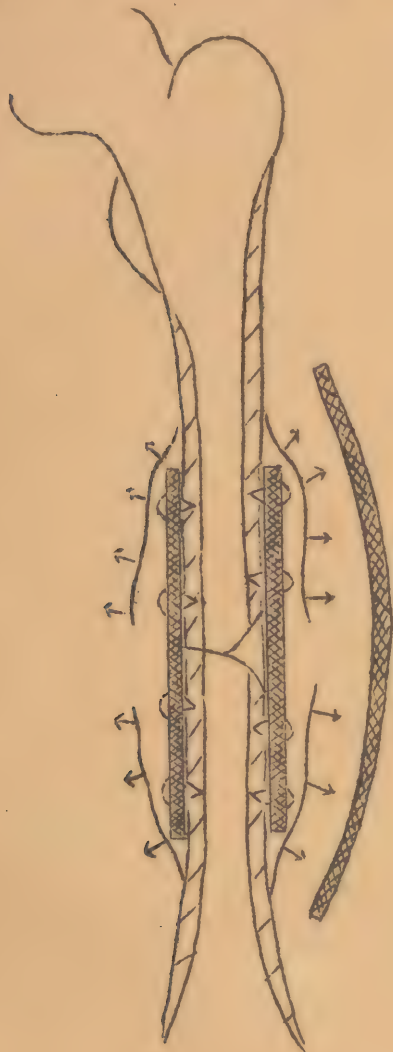


Illustration 131.

Diagram of the same fracture as in illustration 130, in order to show how much callus and periosteum would have had to be removed, if the fracture was treated with 8cm. long Lane's plates.

Of course, the method of operation will vary in the individual cases, but the principle is always the same. It is nearly always possible to approach the place of the bone fracture or of the intended osteotomy by mere blunt separation of the muscles, though it must be admitted that the survey is often less clear than in case of extensive detachment of the periosteum, which often complicates the operation. Quite palpable or visible bony protuberances, etc., which are marked in the X-ray as well, are then used as clues, such as the pointed end of the proximal fragment in the above mentioned example. On the other hand, e.g. in case of an old fracture, the nail can be driven in if only a very narrow area around the fracture cleft is seen. If the fracture is not yet quite fixed by bony healing it is very often possible, even with the femur, to break the fracture apart by powerful bending. It is suitable to do this immediately after the incision of the skin. For this purpose, and to facilitate reduction, a 2 cm. long piece of the fibula is resected in the lower leg in every case. This is necessary as well for the mechanical reasons mentioned above (see chapter III).

Resection of the fibula.

On principle it is of no importance where this resection of the fibula is performed; whether in the upper or lower third or in the middle. It is not suitable to perform the resection at the very level of the fracture, for, if an infection of the place of resection occurs, the place of fracture is endangered as well. In case of resection in the upper third, the peroneus is endangered. The effect of the resection is considerably decreased, however, if the

fibula is severed at some distance from the fracture, i.e. both bones are rather tightly mechanically coupled to each other. The resection is performed best by a longitudinal incision at the outside of the lower leg. The fibula is easily palpated through the skin in most cases. The muscles above the bone are bluntly separated, and then the periosteum connected with the muscles is scraped off the fibula. The muscles are then kept apart by 2 raspatories, introduced deeply. If the fibula is thin and delicate, it can be easily severed with a pair of rib-scissors. With stronger fibulae this is impossible, and then it is the simplest method to perform the resection with a chisel, cutting out a wedge at the proximal and distal ends of the place of resection. The fibula will easily splinter, so the last few points and jagged ends must be removed with Luer's rongeurs. During the operation, some of the numerous deep veins of the calf may be injured and often they bleed violently. In most cases, the hemorrhage will be stopped by pressure and is best controlled by ligation. It is always suitable to insert a rubber drain during the first 24, at most (!) 48, hours, in order to drain the hematoma. This is urgently recommended for all other osteotomies and operative openings of bone fractures as well. It must, by no means, be forgotten to remove this drain in due time, since otherwise an infection of the wound will occur almost without fail.

In case of a fracture of the femur healed with shortening, it is also very often possible to detach the two fragments by the lever effect of a powerful raspatory introduced between them. It is also frequently sufficient to sever the callus partially with a chisel, the rest will break during the flexion. In case of pseudarthroses too, it is sufficient in most cases to cut open one side of the solid capsule of connective tissue with a knife. Then, one can break the pseudarthrosis open.

After the severing, the surfaces of fracture need only some smoothing so that they fit well upon each other and, if necessary, the marrow cavity must be drilled open. All lateral spicules and protuberances of the extra-callus are not removed, in order to avoid any avoidable damage to the periosteum and any unnecessary destruction of tissue and hemorrhage. It will rarely occur that such a callus spicule impedes the establishment of ideal resection. If so, it must be removed of course.

If the poorly healed fracture is some years old, chisel and saw must be used. Even in this case it is only important to bore open the marrow cavities on both sides and to get planes fitting to each other tolerably well. The position of the planes depends on the position and course of the old fracture planes. If a transverse fracture is involved, the 2 sawed surfaces of the fragments must be perpendicular to the axis of the marrow cavity, so that the ends fit as well as possible after the insertion of the nail. Accordingly, oblique sawed surfaces are made in case of an original oblique fracture. These sawed surfaces should pass through the intact periosteum at the place of the original fracture, so that the attached caps of callus are sawed from the ends

of the fracture. These then form broad support flanges at the place of junction, which considerably contribute to a rapid and certain healing. The surfaces must not be located too high nor too low, lest the operated leg becomes shorter or longer, as is shown in illustration 132.

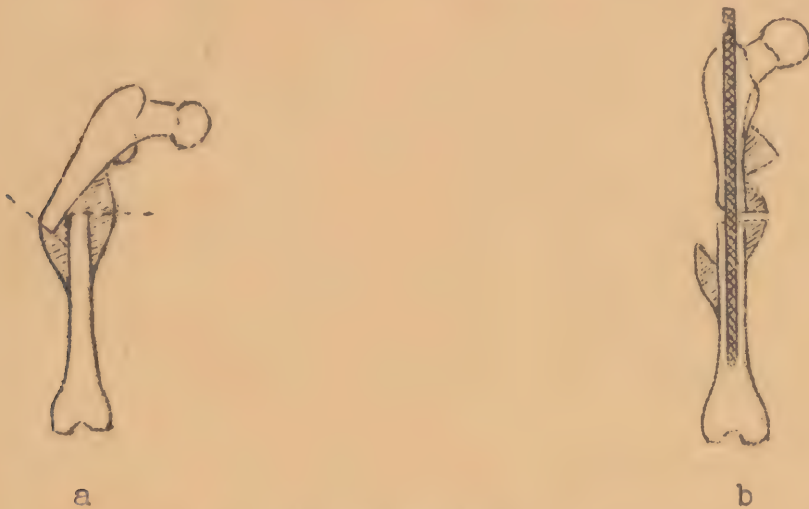


Illustration 132.

Diagram of the marrow nail osteosynthesis of a fracture of the femur healed with marked shortening and angulation. The location of the sawed surfaces is marked with little lines, the chiseled surface is dotted.
a) before marrow nailing
b) after marrow nailing

At the place of osteotomy, a broad flange has been formed.

It must be observed that a piece of the bony mass is often resorbed at the outside so that a small defect will remain after the osteosynthesis. These sawed surfaces usually open the marrow cavities, or render their opening easy. The sawed surfaces being made, the fragments are separated with a large chisel in the direction of the former margin of the compacta between the fragments. In illustration 132 one has to imagine the chisel applied in the direction vertical to the perspective plane, on the dotted line.

Only in particularly favorable developed cases are complicated osteotomy planes like that possible, and they require an extensive exposure at the osteotomy site. For this reason, one can make the operation easier at the upper extremity by resecting the whole place of the fracture and by forming the fracture ends in a suitable shape, since length is not so important with the upper extremity. The union is performed according to the same principles as with the pseudarthrosis, which will be described in particular in this chapter. The splintering up of the ends has proved suitable as well, the splinters then remain in connection with the periosteum and the muscles.

With the lower extremity, however, any shortening must be carefully avoided. During all osteotomies, it is inap-

propriate to prolong the operation. So it will often occur that one has to desist from the establishment of the described exact and broad contact, which may usually be done without concern in case of marrow nailing. Even here, the favorable healing conditions of the method promise satisfactory results.

At this point, it is remarked that the femur and humerus show a considerably greater power of regeneration than the bones of the lower leg and the forearm.

As an example for such an osteosynthesis with insufficient contact, we mention 23 year old B.K. 3 years ago, he sustained a gunshot fracture of the right femur at the border of the lower third. Treated with plaster cast. An almost complete stiffening of the knee-joint occurred, while the fracture was fixed in a favorable position. Because of persistent fistulae maintained by sequestra within the bone a considerable part of the outer wall of the bone was eroded away. The remaining part of the bone was markedly eburnized, and during a walk, it broke as a fatigue fracture with a typical transverse cleft with smooth surfaces (see chapter III). After the war, this type of fracture has been frequently observed, as this operation of "saucerization" has often been performed (principle of removal of an osteomyelitic cavity according to NEUBERT, Kiel). These fractures are very difficult to heal in plaster casts (see illustration 133).

Marrow nailing was performed although a fistula existed (see chapter VII). In order to avoid a considerable shortening, the bone ends could not be prepared to fit exactly. For this reason, the roentgenogram made immediately after the operation shows marked defects at the osteotomy site since so much bone had been lost by saucerization. In spite of that, an excellent healing result was obtained. The gaps were filled because of a sufficient development of callus. The course of healing was without any complications. No plaster cast was applied.

The patient, however, got up from bed and used his leg only 4 months afterwards. After 3 more months, the nail was removed (see illustration 134).

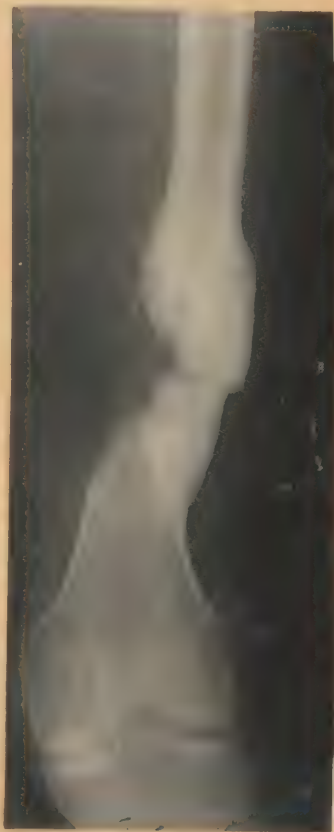
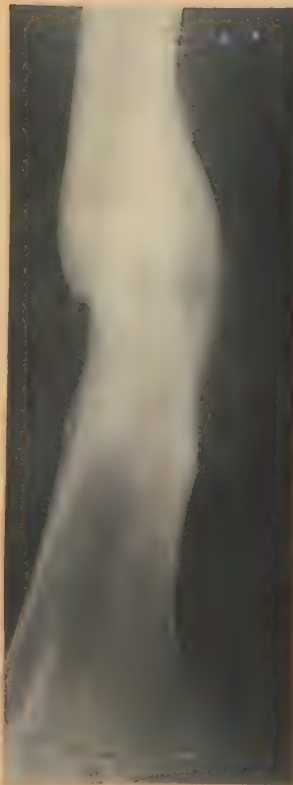
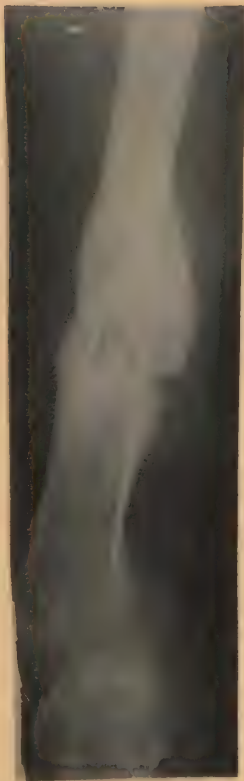
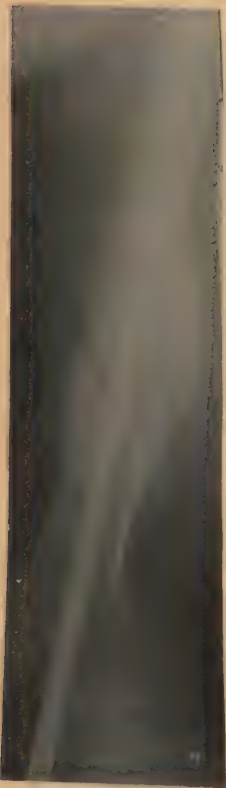


Illustration 133.

Fatigue fracture after "saucerization" of 3 year old gunshot fracture of the right femur of 23 year old B. K. the bone is markedly eburnized at the place of fracture.



a



b

Illustration 134.

The same patient B.K. as represented in illustration 133, immediately after the marrow nailing;

- a) the bone ends do not fit well, since a marked shortening had to be avoided.
- b) The gaps are completely filled with callus 4 months afterwards so the patient can use his leg.

The stability of the osteosynthesis, which is so important as regards bridging over by bones and control of infection, is equal in these cases, if the nail is driven in both marrow tubes. If this is not possible, the cases with exact adaptation of the fracture ends and the masses of callus are more favorable. One might even perform an additional fixation using a plaster cast or splint. On the whole, the principles for the establishment of absolute stability with simple fractures apply here as well (see chapter V).

In addition, complicated sawed planes have the disadvantage that the periosteum is more seriously damaged and that it peels off at the edges of the sawed surfaces despite all care. Only with soft callus is it suitable to use a chisel. With brittle bones, there is the great danger of their splintering. This is a great trouble especially in case of marrow nailing, for the cracks will always run along the shaft and thus force open the marrow tube, so the nail is not held firm.

For this reason, only the saw can be used in most cases. The author has never used the Gigli-saw. It easily causes damages to the periosteum, endangers the soft parts, and, moreover, often breaks. Even a good wire-saw is not capable of severing a hard femoral shaft transversely, nor an eburnized bone. The electrically driven circular saw is hazardous, since it will easily slide off the bone and may cause serious injuries of the soft parts; so it must be held firm with both hands. The best saw is the bow-saw. It may be used in many ways, even cross-section cuts may be made even of the femur, if the patient is not too fat, since the incision of the skin is always performed at the outside in case of a marrow nailing osteotomy. There is only a thin coat of muscles. These are held apart by raspatories or the very practical Hohmann-hooks (see illustration 135).

This cross-section sawing is considerably easier when the fracture healed with angulation. One often need only keep the skin away from the fracture (see illustration 136).

With the bow-saw, the fitting of the fracture ends can be effected very easily. The extremity is put to a sharp angulation, so that the ends approach the wound, then they can be easily sawed. In the demonstrated example of the ulna, both ends can be easily shortened with the saw, so that they fit again with ob-

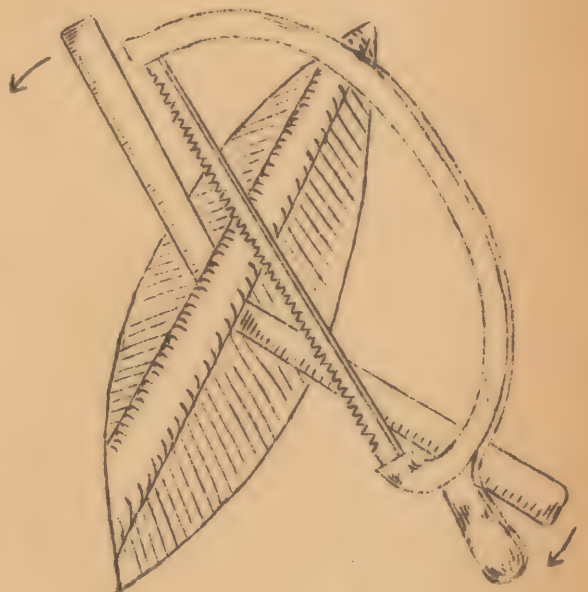


Illustration 135.

Severing of a femur with the bow saw, starting from a long incision of the skin at the outside. The muscles are kept apart by raspatories. Transverse sawing.

lique planes (see illustration 137).

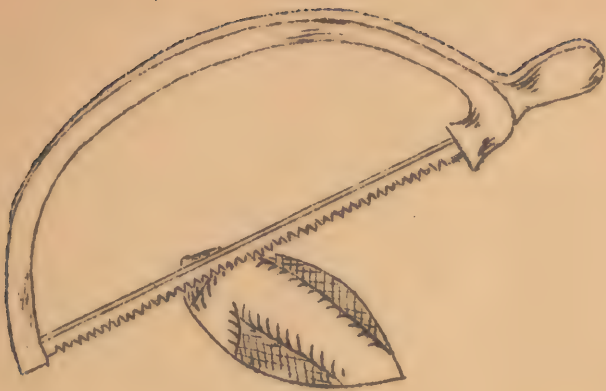


Illustration 136.

Severing of an ulna healed with angulation with the bow-saw. Oblique sawed surfaces.

During transverse sawing the bone is not wholly exposed according to the above mentioned principles. It is still covered by a layer of muscles about $\frac{1}{2}$ - 1 cm. thick. This layer is severed with a knife at the place of sawing in the plane of the section. If the bone ends are shortened, the periosteum is pushed back to the sawed surface, so it is preserved. The bow-saw enables us to shape the bone ends in other forms, such as the step-like freshening of pseudarthroses. After sawing the bone transversely, longitudinal cuts of the desired length are first performed on both bone ends in this case, then the transverse sections are made over them.

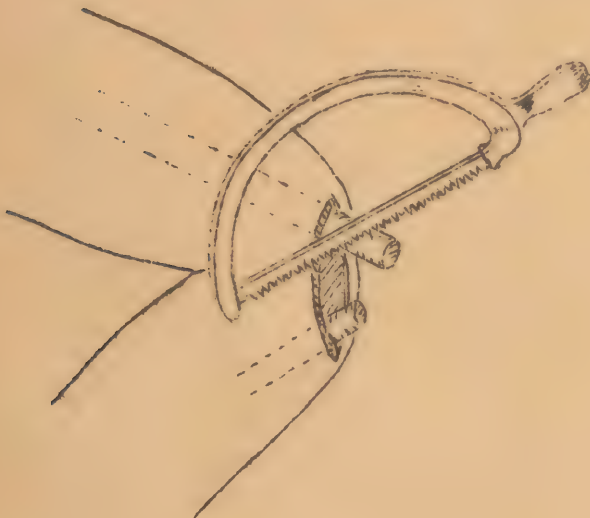


Illustration 137.

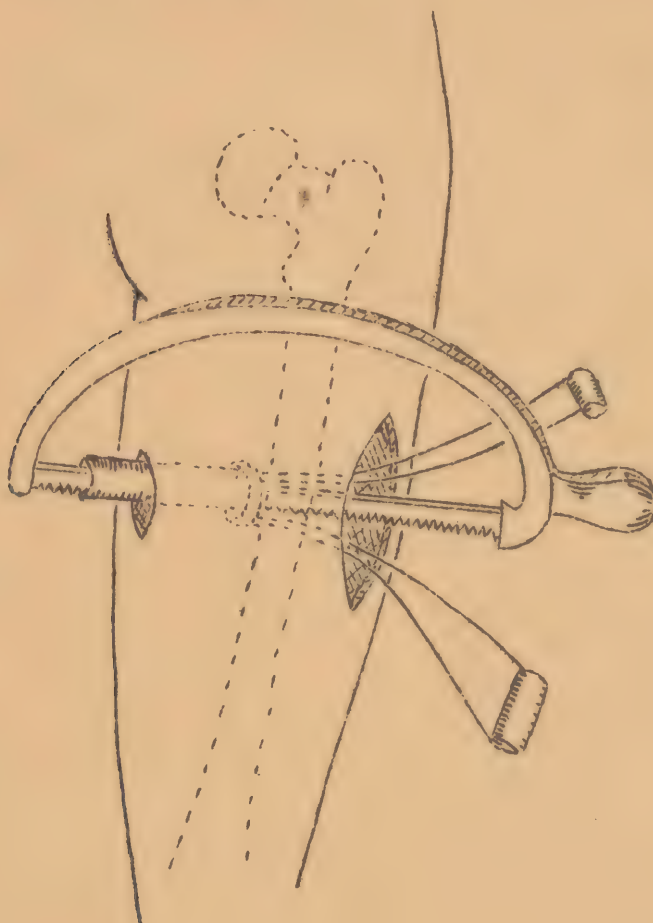
Shortening of the bone fragments protruding from the wound after having been cut with the bow-saw. Oblique sawed surfaces are restored.

If the bow-saw is used during transverse cuts, however, a very long incision of the skin is always necessary, so one advantage of marrow nailing is lost. For this reason, the author described in 1944 a saw which permits to perform this cutting from a very small incision of the skin. This is the counter-incision saw. The bone is exposed as described at the place of operation, then a bullet-forceps is pushed through the muscles past the bone, before or behind it, a method which is known to every surgeon from thousands of operations for the introduction of a rubber drain in case of suppurating processes.

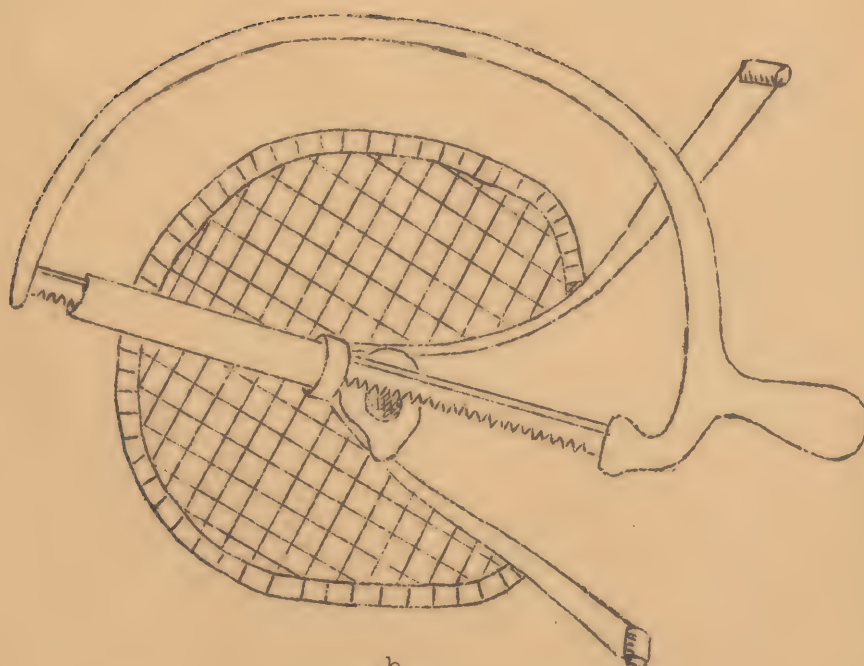
This incision need not be ex-

actly opposite the operative wound, but according to the location of the bundles of vessels and nerves, may be performed more to the front or to the back. The incision over the point of the forceps need only be 1 - $1\frac{1}{2}$ cm. long. No rubber drain, but a thin metal tube is now introduced. Two wire loops are fixed to its end in the operative wound, they are drawn from the operative wound, one before, the other behind the bone. One loop is held by the operating surgeon, the other by the assistant. The saw-blade is now introduced into the metal tube. The blade is provided with a small piston gliding to

and fro in the tube, thus protecting the tube from being injured by the blade. Then, the saw-blade is fixed to the bow-saw on both sides of the extremity. (See illustration 138).



a



b

Illustration 138.

Counterincision-saw according to KUENTSCHER.

a) Performance of a counterincision

b) after introduction of the metal tube.

Both transverse and oblique cuts at any angle to the bone axis are easily performed with this saw from very small incisions of the skin without the slightest hazard of damage to the soft parts, for the muscles are safely kept away from the saw blade by the tube. Since its end is firmly pressed on the bone by the wire loops, no soft parts may slip in between the tube and the bone. These loops keep the wound open and prevent any injury of the soft parts in the operative wound, so no other hooks are necessary in the wound. The metal tube is able to follow any change of the inclination of the saw-blade in relation to the longitudinal axis of the bone. In aseptic cases, the counterincision is closed again immediately after the saw is removed. In septic cases, the tube is replaced by a rubber drain, if necessary. The saw can be used both with thin forearms and with the thickest femurs.

A severing without splintering from a comparatively small incision of the skin may also be performed with the electric drill. A number of holes are bored in the intended line of separation, which are then joined to each other by the chisel. This method takes up much time and involves the hazard of a necrosis of the bone through heating at the place of drilling.

It must be the objective of every operative technique to reduce to a minimum all injuries of the tissue and necroses, since they impair the conditions of healing and increase the hazard of infection. For the same reason, one should keep the incision of the skin as small as possible. But this must not complicate the operation and thus prolong it, for a longer operation involves the same dangers by drying of the wounds, possible infection from the air, the operator's hands, etc. In addition, there are the hazards of constant loss of blood and of shock in case of large wounds. All this applies in particular to osteotomy.

In chapter I, these hazards and disadvantages of an operative treatment of the fracture have been described in detail. By experience, the most careful asepsis, and a good technique, one may avoid them or reduce them to a large degree, particularly by using marrow nails, because this method permits joining the fragments without considerable damage to the soft parts and to the periosteum and because this operation may be performed in considerably less time after some practice. But it must also be possible to finish the first part quickly, for really serious dangers or even death by shock will only occur if the operation lasts too long. This has been discussed before in chapter IV. Practically, it is only the osteotomy of the femur which is hazardous in this respect, for here really great difficulties have to be overcome in case of old fractures. The fracture ends are imbedded in the midst of thick muscles, and though cicatricial tissue grows luxuriously around them. In addition, considerable hemorrhages complicate the operation considerably in this area. Vision is considerably impaired by the irregular form of the callus, and it is, besides, hardly possible to separate the cicatricial tissue from the callus. Together with the shortening of the muscles, the cicatricial tissue makes reduction extremely

difficult. For this reason, even an experienced orthopedic surgeon often requires several hours to perform the operation. But this must be avoided if possible and one cannot warn against this urgently enough. The author recommends in such cases that the osteotomy be performed in two operations. Why should this principle, so successful in abdominal surgery, not apply to certain cases of bone surgery as well? In addition, there is only a small number of these cases. In case of such a complicated osteotomy of the femur, one might, for instance, perform the operation to the point where the osteotomy site is clearly demonstrated. Then, the operation is interrupted after carefully controlling the hemorrhage and the skin is sutured. If necessary transfusions, infusions, etc. can be now administered. 8 - 10 days later the wound is reopened, and the cutting of the bone, reduction and marrow nailing can now be performed at once. With this method, however, a considerable delay may be occasionally caused by an infection subsequent to the first operation. But even in this case the patient has been certainly saved from a more serious inconvenience, viz. an infection of the bone wound.

B. Technique of marrow nailing during osteotomy.

During osteotomy the introduction of the nail is much more simple than in the percutaneous nailing of a fresh fracture (chapter V).

The marrow cavity is opened, and the nail is introduced under direct vision. It is unnecessary to use the X-ray, it may be used at the end of the operation, to control the result. In case of poorly fixed fractures, the marrow cavity is open already, in the rest of the cases, it can be easily opened with the awl, which, causing no heat-necroses, should be preferred to the electric drill. The electric drill is of a complicated structure and may even fail sometimes, though in some cases of old pseudarthroses it is occasionally necessary to use it. In these cases, the marrow cavity is often closed by hard ebarnized bone several centimeters in length. With the lower leg, upper arm, and forearm, the nail is then introduced from a place outside the fracture as in case of percutaneous marrow nailing and is visible in the wound in the marrow cavity of the one fragment. It need only be introduced into the marrow cavity of the other fragment, then the nail is driven in finally. Thus, the osteosynthesis is accomplished.

In case of operations of the femur, it is recommended to lay the patient on his side on his sound leg. Then the incision of the skin is located on the lateral aspect, which affords a convenient approach to the bone without endangering large vessels. The metal guide rod is introduced into the opened marrow cavity of the proximal fragment and pushed up to the top of the trochanter major, where it easily pierces the very thin compacta of that area with a perceptible jerk. Its point is then palpable under the skin of the buttocks. This point is exposed by an incision of the skin 1 - 1½ cm. long. The nail is now pushed on this point and driven in, until it protrudes about ½ cm. from the marrow cavity of the proximal fragment (see illustration 139).



a

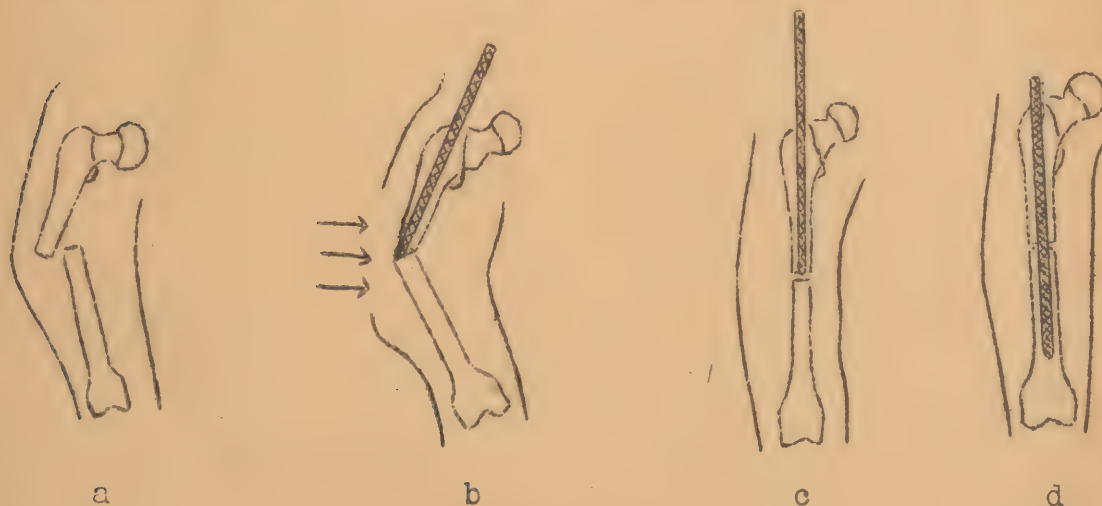
b

Illustration 139.

Technique of marrow nailing during an osteotomy.

- a) Introduction of the guide rod into the osteotomy wound, its point is palpable through the skin and is exposed by a stab incision,
- b) the marrow nail is pushed on the guide rod and driven in.

In most cases, it is possible even with the femur to place the bone fragments on each other and to drive the nail in the distal marrow cavity. If the patients are robust and have a shortening due to an old poorly healed fracture, not even considerable pulling by means of an extension apparatus can correct the shortening. In addition, these femurs usually are in a varus position, but after cutting the bone at the old fracture site it is always possible to place the fragments on each other by angulation. The apex of this angle is lateral, that is out of the wound, as shown by the diagram of illustration 140.



a

b

c

d

Illustration 140.

Diagram of the osteosynthesis of an old fracture of the femur with marked angulation

- a) before the operation
- b) after the cutting, the fragments are placed on each other with angulation
- c) the fracture is reduced by powerful bending to a straight position in direction of the three arrows, so that
- d) the nail can finally be driven in.

An assistant now forces this point medially until the bones at the osteotomy site are straight, as indicated by arrows in illustration 140b. In this process, the bone must often be pressed surprisingly deep into the musculature. When the angulation is corrected and the fragments are in a straight line, the nail is quickly driven in. The straightening is facilitated by a strong pull exerted by the extension apparatus of the table, which is connected with the foot by a set of pulleys. It is absolutely necessary to pay attention to the fact that it is possible to drive the nail in only if the angulation is completely corrected. One more technical maneuver must be observed in those proximally located osteotomies which are at about the level of the trochanter major, e.g. in the case of subtrochanteric osteotomies. There exists, owing to the width of the marrow cavity, the hazard that the tip of the rod inserted in the described way, may penetrate too far medially and may even endanger the hip-joint. For this reason, one must either press the lower end of the rod as far as possible to the medial side, as illustration 141 shows, or the rod must be inserted in the trochanter tip from the proximal end

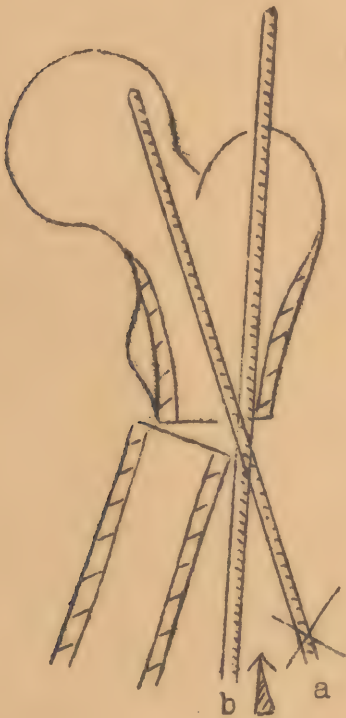


Illustration 141.

Insertion of the guide rod during the subtrochanteric osteotomy;

- a) wrong insertion. The tip gets too far medially. This is avoided by:
- b) correct insertion with powerful pressing of the handle of the rod in the direction of the arrow.

with considerable adduction of the proximal fragment as in the case of simple fractures (see chapter V). This procedure is recommended also in those cases where the osteotomy site cannot be exposed to such a degree that the rod can be easily inserted, e.g. in the case of a gunshot fracture. Then the appearance of the rod in the osteotomy wound is checked by direct vision, in cases of gunshot fractures it is palpated with the finger or even perhaps made sure in the X-ray. During subtrochanteric osteotomies, one usually includes the trochanter tip in the operative wound anyhow, which facilitates the procedure considerably. If one does not proceed in this way, it is often suitable not to cut the bone completely during the osteotomy but only to such an extent as necessary to control the correct location of the rod. It is recommended to drive the nail in the proximal fragment at once, so that one can control its position, since the musculature has the pronounced tendency to abduct this fragment violently, and this complicates the operation considerably.

With the remaining bones, the technique of marrow nailing is the same as described in the preceding chapter in case of simple fractures, so the lower leg nail is driven in from the tuberositas tibiae to the point where it protrudes out of the exposed marrow cavity of the proximal fragment, and then, its point is inserted into the marrow cavity of the distal fragment. The upper arm and the ulna are nailed from the proximal or distal side, the radius from the distal side.

As regards the osteosynthesis of the clavicle, a thick Kirschner-wire is usually sufficient as a marrow nail. Starting from the wound, it is first inserted into the distal marrow cavity with an electric drill and drilled in so deeply that it pierces the skin and protrudes far from it. Then the wire is obliquely cut off the drill with the forceps. So this end acts as drill-point. The drilling machine is now attached to the wire end protruding from the skin. The wire is now drawn back to the point where its end can be easily inserted into the proximal marrow cavity, then it is drilled forwards towards the sternal end. Then, the skin at the shoulder is incised at the place where the wire protrudes from the bone, the wire is bent and fastened to the bone according to RAUCHENWALD's technique (see chapter V). The described procedure is demonstrated schematically in illustration 142.

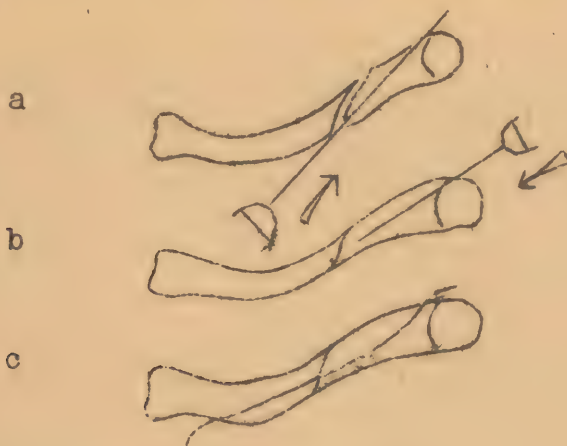


Illustration 142.

Scheme of marrow nailing osteosynthesis of the clavicle. A thick Kirschner-wire is used as a marrow nail.

- a) Insertion in the distal fragment.
- b) Thereafter, the wire is obliquely cut, and the drill is attached to the other end. Then
- c) the wire is drilled into the proximal fragment towards its sternal end.

One may also use wires with both ends sharpened, which makes the cutting unnecessary.

Mistakes during the marrow nail osteosynthesis of the clavicle.

The drill pierces the compacta and emerges from it with its point. It may possibly injure vessels and nerves when it does not run precisely in the direction of the marrow cavity. At all events, the marrow nailing must be performed with the utmost care. Because of the S-shaped bend of the bone, the point of the drill often does not arrive at the sternal end, but comes out the front of the bone before, which is observed at once, since the bone is visible in its whole length under the skin. This is no serious danger, then the bone is exposed at that place and the nail bent round according to RAUCHENWALD. Besides, one can also according to the author, simply turn the ends back sharply where they protrude from the skin at both sides, cut them short and make the cut ends disappear under the skin through the incisions by drawing back the skin with a pair of tweezers. This procedure has yielded excellent results during a temporary osteotomy of the clavicle because of an aneurysm of the arteria subclavia. In this case, the clavicle was cut obliquely and rejoined not by wire suture as usual, but by marrow nailing as described above. The synthesis was so exact that it was not recognizable in the X-ray made immediately after the operation (see illustration 143).



Illustration 143.

Marrow nailing of the clavicle after its temporary resection because of an aneurysm of the subclavia. X-ray taken immediately after the operation. The osteosynthesis is so exact, that the osteotomy cleft is not recognizable.

The marrow nailing of the phalanges and metacarpal bones is performed in a similar way. We mention some examples: AS a consequence of a shell splinter injury of the wrist, which healed in an unfavorable position in the 34 year old A. S. 2 years previously. An excessively extended position of the metacarpo-phalangeal joints 2 - 5 and loss of the thumb, so he could not bend his fingers nor form a fist. He practically could not use his hand. The metacarpals were obliquely osteotomized with a chisel,

and marrow nailing was performed by means of Kirschner-wires in the way described with the clavicle. The wires were bent back. The X-ray showed that the places of osteotomy were located not, as intended, in the middle of the bones, but



a



b



c

Illustration 144.

Marrow nail osteotomy of the finger metacarpals 2-5 of the 34 year old patient A.S. because of excessively extended position of the fingers in the metacarpo-phalangeal joints after 2 year old shell splinter injury.

- a) before the operation
- b) after oblique osteotomy and marrow nailing
- c) after removal of the nails, 6 weeks later.

far to the distal end. The mistake was caused by the fact that orientation was very difficult in the much deformed hand covered with scars. All the same, an excellent result was obtained. The fingers retained the position they were expected to retain after the marrow nailing. A fist could be formed now, and the fingers could be stretched almost straight. The healing course was without complications. The nails were removed 6 weeks later (see illustration 144). It is intended to replace the lost thumb. Marrow nailing has proved effective here also.

Replacing of fingers.

According to KLEINSCHMIDT's method, who made splinters of the tibia heal under the abdominal skin, the author implanted two 6 - 8 cm. long pieces of the fibula in the abdominal skin. A 3 cm. long incision of the abdominal skin was made, and then a canal was made with a straight bullet forceps. In this canal, the carefully resected piece of the tibia with periosteum was inserted and the wound closed. According to the author's experience, such a defect of the tibia causes no functional disturbance whatsoever.

The fibula requires 3 months to heal in. Then, the fibula together with the skin is lifted and two incisions of the skin are made parallel to it, so that this segment of the skin can be made into a tube without tension surrounding the bone. 8 days later, the skin bridge on the lateral side is half-incised, 8 more days later, the skin-tube is wholly separated and the bone, together with the skin-tube is nailed on the wrist. 3 more weeks later, the skin-bridge at the fracture is again at first half and after 8 more days completely removed. Of course, these fingers cannot be moved, but they are very useful if all other fingers except the thumb or vice versa are missing, so that the hand is a prehensile organ again. This method of transplantation of bone splinters according to KLEINSCHMIDT's principle appears to be the only possibility of transplanting bones, considering the hazard of infection with the wounds of this war (see also the following paragraph).

In case of juvenile patients, it may also be possible to follow NIKOLADONI's example and to nail toes as substitutes for thumbs, thus preserving movable joints. This had not been possible previously because of the required long fixation in a plaster cast.

In one such case, the 2nd - 5th fingers of the left hand had been lost by a shell splinter injury. In addition the patient had serious injuries of both elbows, forearms and upper arms with fistulae persisting for several years. The patient was 36 years old, the injury was 1½ years old. The thumb was quite movable, the elbow-joint firmly fixed by bone and markedly fistulous. A removal of sequestra from the trochlea humeri with broad flattening of the joint

was made. Despite the suppuration the resection of the radius head was performed (see chapter VII) which yielded an excellent result with almost complete pronation and supination of the hand. A finger was now implanted by marrow nailing in the prescribed way, and the hand, useless before, became again a good prehensile organ.

The marrow cavity of the thumb is wider, so one requires fairly strong nails. As an example, we mention the 54 year old patient W.W. Two years ago, he sustained a serious injury of the right hand by a shell splinter. The thumb was stiffened in the joint at the base towards the back of the hand, so that opposition was impossible. Thus, the hand could not be used. In the middle of the metacarpal an oblique osteotomy was performed and a curved marrow nail driven in from the proximal side. This nail had been prepared from a 4 mm thick V2A steel wire. Its end was bent before it was driven in. The hole at the base joint, into which the nail was driven, was prepared with an awl. (See illustration 145).



The thumb healed in good opposition - position without any complications. Flexion and extension was retained in the joints of the thumb, so the patient was again able to write with his right hand.

C. Indications for marrow nail osteotomy.

Generally speaking, the indications for marrow nail osteotomy are:

1. a poorly fixed fracture,
2. a fracture healed in an unfavorable position,
3. a fracture healing with delay or not at all (pseudarthrosis),
4. a deformation of the bone,
5. tumors of the bone.

Illustration 145.

Condition after marrow nailing of a thumb stiffened in extreme dorsal flexion subsequent to a 2 year old war injury of the 54 year old patient W. W.

1. Marrow nailing of a poorly fixed fracture.

If, according to the author's procedure, every fracture suitable for it is treated with marrow nails, this indi-

cation does not occur from the first in most cases, but, as described in chapter VIA, pseudarthroses do occur even after marrow nailings when no "stable osteosynthesis" was obtained.

It happens, however, comparatively often in the plaster cast or traction method that either the fracture cannot be fixed in a favorable position, or as is the case much more frequently, that the initial favorable position is lost in the course of the treatment, but this is usually noticed too late. The interposition of muscles which may make reduction impossible, is much more rare than generally assumed. No other impediments to reduction exist. There are a series of fractures with which poor results have been obtained by conservative treatment, as shown by experience. Some surgeons include the oblique fractures of the tibia in this group. The tendency of the surgeons for the operative intervention, however, is different in the various countries. On the other hand, there is greater agreement as regards the time when such a fracture should be operated. The majority of the surgeons consider the middle of the second week the most favorable time. BLOCK mentions here the names of CIMINATA, DAHL-IVERSEN, DEMAL, GOETZE, KEPPLER (BIER), KIRSCHNER, KOENIG, LAMNOTTE, MATTI, MAGNUS, SPEED, WIDENHORN. At that time, the mechanical inflammation with its marked acidification in the surrounding area subsides due to decomposition of cells. The necroses are largely absorbed. The operation causes a new mechanical inflammation with a new increase of hydrogen ions, as R.A. SCHMIDT was able to prove. If the chemical conditions of the wound are disturbed like that, an infection doubtlessly can develop more easily, since the germs find favorable conditions in acid environments. Also the unfavorable increase of a local infection, e.g. in case of a furuncle, is principally caused by a shifting of the equilibrium of the ions, and, above all, by the rapid increase of concentration of the hydrogen ions against which the mechanisms of regulation of the body fail. Under the microscope, a delay of callus formation and chiefly an increase of decomposition can be proven. According to KOENIG's X-ray studies, foreign substances increase the decomposition of the bones and delay the healing, if they are effective at the time of its most intense regeneration. The decomposition is followed, it is true, by an intensified formation of callus.

On the other hand, there are surgeons who consider another time of operation more favorable. Thus, REHN, whose experience is considerable, operates in the first few days, as long as the muscular inactivity still exists, so he has the advantages of easier reduction. LEXER operates, if possible, only after 4 weeks, when the hyperemia in the area around the fracture is most pronounced.

When such a fracture is presented for marrow nailing because of unsatisfactory position, one should lose no time and nail it at once, if the method is suitable at all for the case. Of course, the principles for the nailing of simple fractures apply to osteotomies as well. At all events, it should be first tried to nail the fracture without operative exposure. In a vast number of cases where the fracture may be reduced but not be retained in a favorable position in a plaster cast or by the traction method, this is successful and will spare the patient the osteotomy.

But even in those cases where no reduction was possible with the usual means, one should always try once more to obtain a closed marrow nailing. As experience has shown, this is almost always possible since marrow nailing has necessarily developed methods of more effective reduction (see chapter V). For this reason, the operation should be performed as early as possible because reduction is easier and motion of the extremity and thus normal circulation is restored earlier.

If reduction fails, one will at once perform an operative reduction with the patient in the same position. For this reason, everything must from the first be prepared for this circumstance, lest the operation is uselessly prolonged, lest narcosis need be prolonged, etc. Only a very small incision need be made usually, and then it is often surprisingly easy to place the fracture ends on each other by means of bone hooks. The maneuver of inserting a raspatory between the fracture ends and of reducing the fracture by its lever-effect, has been often successful. Then, a guide rod and subsequently the nail is driven in the distal fragment, a rubber drain is inserted, and the skin is closed by sutures. Muscle sutures are usually unnecessary. One will, at most, close the fascia by a few sutures. Buried sutures are to be avoided, if possible. One should not make up one's mind too late, concerning this operative reduction, lest one loses too much time. By efforts at reduction protracted through hours, the patient's life is greatly endangered by the shock-effect, as BOEHLER rightly emphasizes again and again.

If the fracture is older, callus masses of connective tissue and bone have already been formed which render a reduction without operative opening impossible. It may also be prevented by a shortening of the muscles. In these cases, it is useless from the first to lose time by reduction maneuvers. One only injures the patient and the tissue if one is then forced to open the fracture after all. On the other hand, a brief trial does sometimes pay. It is surprising that it is possible to obtain a relatively easy reduction in some cases where even little clouds of callus are observed. The roentgenograms of those marrow nailings look as if the nailing had been done weeks before.

It is unnecessary to mention examples for the marrow nailing of poorly fixed fractures. All the fractures in juvenils illustrated in this monograph are such cases, since marrow nailing with children was made only if no satisfactory position could be obtained with conservative treatment (see chapter V).

2. The marrow nailing of fractures healed in an unfavorable position.

Here the question of what is to be understood by an unfavorable position is much more urgent than in the case of a poorly fixed fracture, for firstly it is never possible

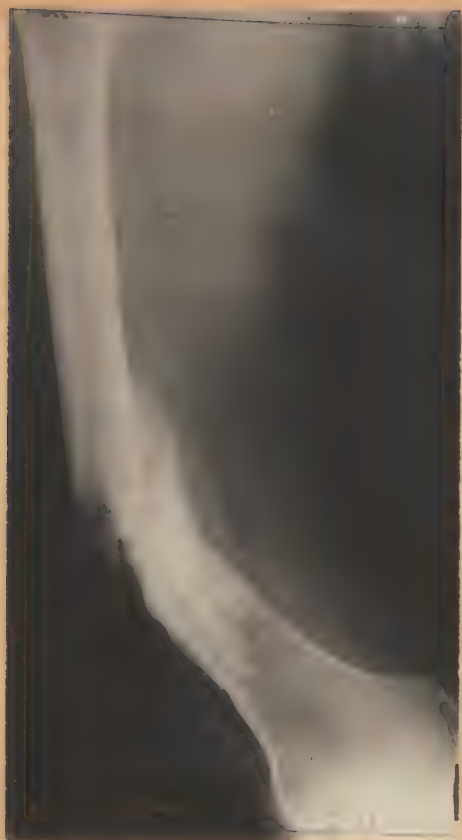
to perform the nailing without opening the fracture, and secondly the operation is at the same time always much more serious, because the bone must be cut. For this reason, the responsibility for such a decision is much greater. One must agree with BOEHLER who asserts, that the indications for operative fracture treatment are made too frequently. A lateral shift for the width of the shaft is of no importance, if the axes of the fragments run in the same direction. In the upper arm, an angulation of 30° involves no functional failure, but in the femur even an angulation of 10° impairs the function of the joint, according to BOEHLER. Only a functional indication can justify the risk of an operative reduction and in this sense we may define an unfavorable position of a fracture as one that causes a constant considerable functional disturbance, so that a shortening amounting to more than 3 cm. causes a considerable disturbance of gait, a marked angulation of the upper arm considerably reduces the ability of using the arm. Of course this also depends on the occupation and profession of the patient. In the individual case, the operation depends wholly on the kind of the dislocation.

a. Procedure in case of dislocatio ad axin.

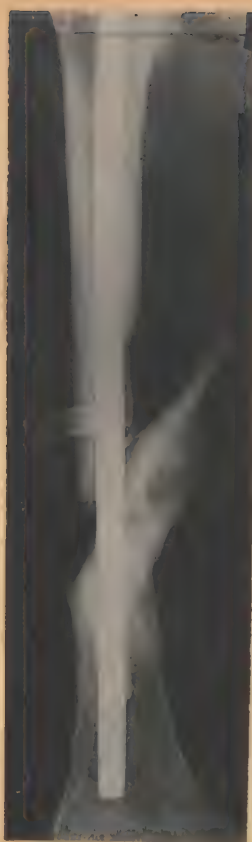
In the upper extremity, only very marked angulations involve a functional failure. We mention, as an example, the case of the 26 year old patient R. P. He had a 1 year old shell splinter injury of the left radius and of the left ulna, just below the elbow joint, which had healed almost in a right angle position and impaired the use of the arm considerably. The bones were comminuted; pronation and supination were impossible. A 5 cm. long incision of the skin was made where the ulna was curved most, and almost a 3 cm. long piece of the ulna was resected at that place with oblique sawed surfaces by means of a bow-saw as described above. Then, a marrow nail was driven in from the olecranon.

Three months later, the marrow nail was removed, and 9 months later, the radius head was resected. A pronation and supination mobility of the hand, restricted by about 30° , complete flexion of the hand, and complete flexion and extension in the elbow joint were obtained, so that P. can carry on his trade as a tailor again.

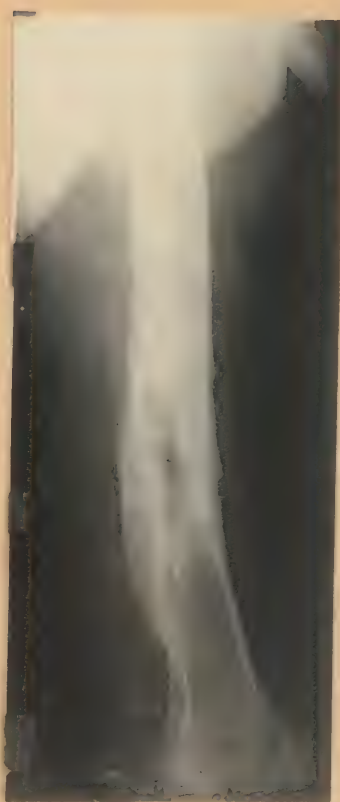
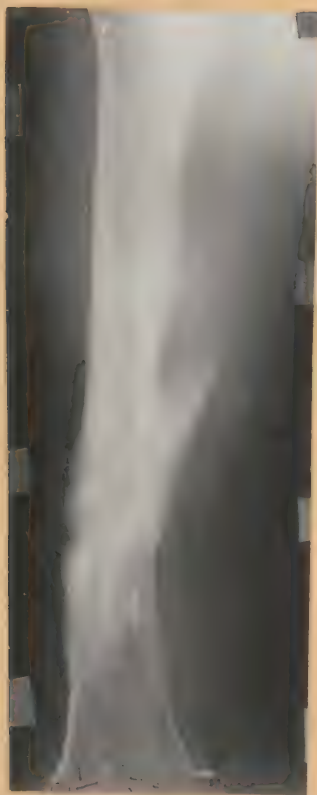
In the lower extremity, even slight digressions from the straight axis involve considerable disturbances. Also in these cases, the angulation facilitates work with the bow-saw, since the leg usually heals in a bandy-leg position. For this reason, the angulation points outwards and presses the musculature apart. Thus, practically no muscles need be separated when the incision of the skin is made during femur marrow nailings. As an example, we mention the 34 year old patient L. W. He had a 2 year old traumatic bandy leg caused by a gunshot fracture of the left thigh. The wounds drained considerable pus for a year and finally healed. There was a marked axis-angulation of the femur in the middle with a shortening of about 7 cm. (see illustration 146).



a



b



c

Illustration 146.

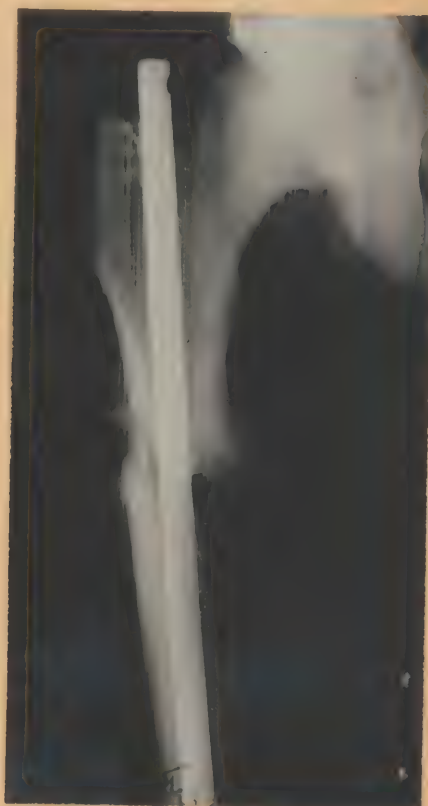
- a) Traumatic bandy leg caused by 2 year old gunshot fracture of the 34 year old patient L.W. Shortening of 7 cm.
- b) after marrow nail osteotomy
- c) after removal of the nail, 18 weeks later; the shortening is completely corrected.

A 6 cm. long incision of the skin was made over the place of the sharpest angulation. The bone was sawed at its outside and then broken. There was some splintering in the longitudinal direction. Marrow nailing was made in the described way. A violent suppuration lasting 2 months occurred, with temperatures up to 40° . No plaster cast was required. Six weeks later, a tube abscess at the back surface of the femur was incised. The patient could get out of bed only after 11 weeks. The femur healed in a straight position with good callus, the fistulae closed. The nail was removed after 18 weeks (see illustration 146).

The patient H.B. was a similar case. A marked angulation of the femur had existed for 8 months after a gunshot fracture. It was a transverse fracture, which had healed in pure dislocatio ad axin. These transverse fractures are quite favorable for osteotomy. There existed a seeming shortening of 13 cm. The marrow nail was inserted from a small incision of the skin at the outside (see illustration 147).



a



b

Illustration 147.

One year old gunshot fracture of the patient H. B. healed with marked angulation. Seeming shortening of 13 cm.

- a) before marrow nail osteotomy,
- b) after marrow nail osteotomy.

The shortening was not only completely corrected, but the leg was even 1 cm. longer, since the callus had not been removed. The patient H. W. had a 4 year old traumatic

bandy leg, caused by a simple fracture after an accident with a motorcycle. The seeming shortening amounted to $3\frac{1}{2}$ cm. The bone was completely developed and was extremely hard. A wedge was cut out of the tibia, thus a transverse fracture plane was formed. The wedge had been exactly calculated previously. Also the fibula was resected. It took rather a long time - 4 months - until sufficient callus had developed. This delayed healing may be explained by the marked eburnization of the bone, partly also by the transverse plane of osteotomy. The final result, however, was excellent. The shortening was corrected, the leg was absolutely straight, the joints were freely movable (see illustration 148).



Illustration 148.

4 year old traumatic bandy leg caused by motorcycle accident of the patient H.W. Marrow nail osteotomy after wedge-resection
a) before the operation
b) immediately after the operation
c) after extraction of the nail, 4 months later.

This wedge-resection has three disadvantages:

The wedge must be exactly calculated and also exactly sawed out, so that the fragments fit after the osteosynthesis. A transverse fracture plane is formed. Mathematically, this is the smallest possible plane of contact of the fragments. The oblique sections produce larger planes of contact and thus better healing prospects. If the nail is not absolutely firm, the transverse plane cannot prevent a rotation of the fragments. For this reason, the author has also operated such pronounced angulations according to HELFERICH's principle of the oblique osteotomy. The bone is obliquely cut with a saw at the level of the most marked angulation. The inclination of the sawed surfaces is of little importance. At all events, it need not be as exactly calculated as the wedge during the wedge-resection. With short sharp angulation an angle of about 45° , with long flat angulation a somewhat more sharp angle to the longitudinal axis is recommended. One must, however, see to it that the axis of the sawed surface with the angulated plane passes exactly through the vertex of the angulation and precisely cuts the angle of angulation in half. Otherwise, the section surfaces do not quite fit; for if a straight marrow nail is used, the bone must be completely straight eventually, no matter how it is cut (see illustration 149).

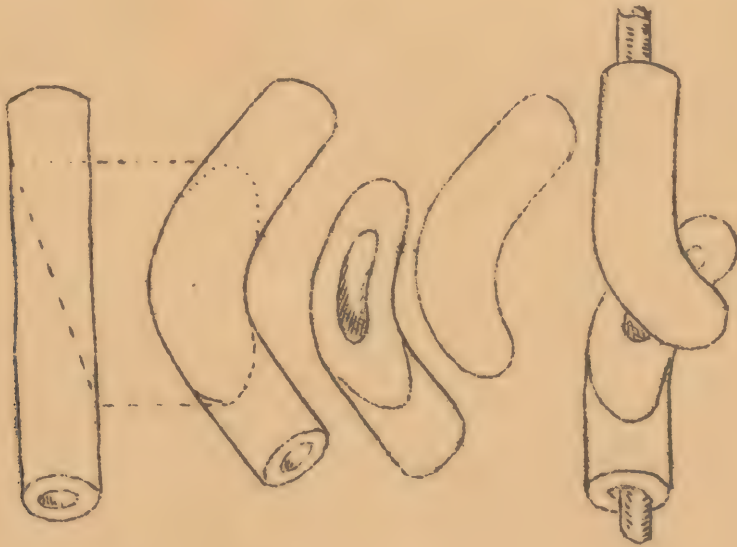


Illustration 149.

Oblique osteotomy according to HELFERICH in case of bones with marked angulation.

As shown by the illustration, no bone is wasted as in the case of wedge-osteotomy. Two bone prominences occur but they have no disturbing effect.

We mention an example for such a marrow nail osteotomy of the femur. It is a 3 year old closed fracture of the femur after an accident to the patient E. O. (see illustration 150).



Illustration 150.

Example of a marrow nail osteotomy with use of HELFERICH's principle. Three year old fracture of the femur of the patient E. O. The callus formed considerably faster and more intensely than in the preceding case.

b. Correction of the dislocatio ad peripheriam.

This dislocation is comparatively rare. It occurs as a mistake even after marrow nailing, if, during the osteosynthesis, the correct rotation-position of the distal fragment was disregarded, or if the synthesis was not stable enough in case of a transverse fracture.

In the upper extremity, the author recommends the step-like shortening. The bone is transversely cut with a saw at any place one chooses, then a longitudinal section about 2 cm. long passing through the central axis is made on the one fracture end. Thereafter, the bones are rejoined and the arm is brought in its proper rotation position. The prolongation of the longitudinal sawed section to the other fragment is marked with a knife by incisions into the periosteum of the other fragment. The end of this fragment is then caused to protrude from the wound by bending the extremity, as has been described before, and a longitudinal sawed section is also made there. The periosteum with the possibly adherent soft parts is now scraped off on the one fragment on one side, on the other fragment on the opposite side. These exposed halves are then cut off by corresponding transverse sawed sections. A simple trans-

verse cutting and marrow nailing is usually not certain enough, since the shortened musculature acts powerfully to restore the former dislocation (see illustration 151).

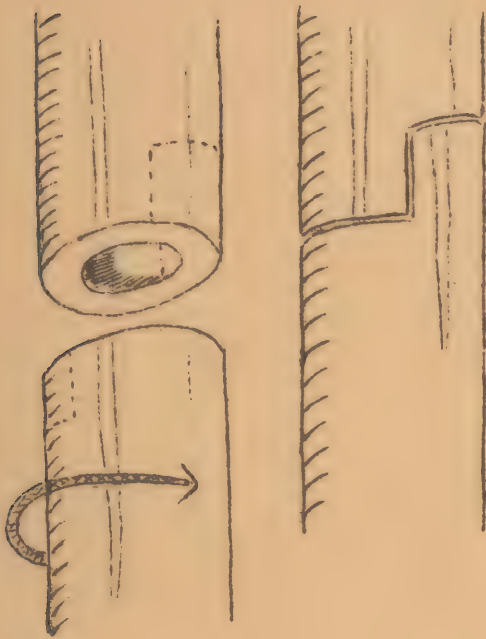


Illustration 151.

Diagram of the rotation-osteotomy by step-like shortening according to KUENTSCHER.

c. Correction of the
dislocatio ad latus.

This dislocation alone is rarely an indication for osteotomy, since a lateral dislocation even as much as the width of the shaft involves no functional failure whatsoever, if it is not combined with another dislocation. But greater lateral dislocations are rare, because in this case a very long callus-bridge is necessary. These cases usually become pseudarthroses. As there is no shortening, osteotomy presents no technical difficulties here.

As in case of every shortening of the upper extremity, an additional contrivance is necessary to prevent a new elongation. It is described in particular in the section on pseudarthroses.

With the lower extremity, this method must be used with great care, lest any greater shortening occurs. Only one step of only 1 cm. is sufficient. If the leg is considerably shortened, however, any additional shortening is a serious loss. If necessary, an additional elongation-osteotomy should be performed. Then, special nails are used. At some distance from the osteotomy-site, 2 lateral bolts are driven in through slits, as when Y-shaped nails are used (see illustration 152).

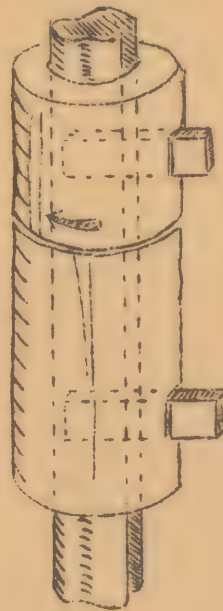


Illustration 152.

Rotation-osteotomy with marrow nailing according to KUENTSCHER. There are only a few cases in which large steps are made in the lower extremity viz. in which marked shortenings do not matter. This applies if the other leg is missing or shorter.

d. Correction of the dislocatio ad longitudinem cum distractive.

With the long tube bones, this dislocation is rare too, but statistics contain numerous cases where fractures of the femur healed with elongations up to 7 cm. and even more because of excessive pulling during the traction treatment. These cases can be effectively treated with a shortening osteotomy by means of marrow nails as described in the following paragraph.

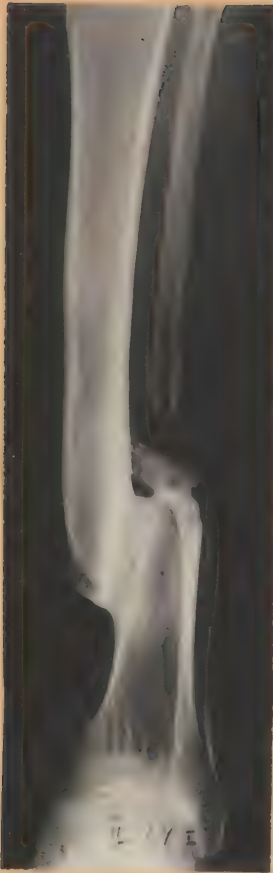
e. Correction of the dislocatio ad longitudinem cum contractione.

This dislocation is always associated with a dislocatio ad latus, but also with other dislocations, for all these cases usually are combinations of various dislocations. The operative procedure of marrow nailing depends on the most evident dislocation. With a shortening without angulation, the osteotomy is frequently very simple. The cleft between the two fragments is usually clearly visible or palpable through the muscles. Then a broad chisel is pushed through the musculature, which runs in the same direction as the cleft. Thereafter, the chisel is driven through the bone bridge with powerful blows. The bone bridge is now completely severed by twisting the chisel and powerful bending. The separation is usually made rather smoothly along the corticalis of the one or the other fragment. Then, the fracture ends are brought more to the surface by further bending, and the marrow cavity is drilled open. The reduction is performed in the manner described at the beginning of this chapter, by V-shaped arrangement and subsequent pressing the fragments into a straight position. As an example of an almost pure shortening dislocation, we mention the 21 year old patient G. D. He had a 2 year old shortening of the lower leg amounting to 4 cm. caused by an accident. The fracture was located the width of a hand above the ankle joint. A longitudinal incision was made at the front edge of the lower leg. Marrow nailing osteotomy was performed in the described way, and the shortening was completely corrected. (See illustration 153).

The lengthening of the lower leg caused a pes equinus, which was corrected by tenotomy of the Achilles tendon according to VULPIUS.

As an example of the correction of a combined dislocation, we mention the patient E. F. As sequelae of a 2 year old gunshot-fracture of the femur, there existed a shortening, lateral dislocation and angulation, in the nature of a bandy leg. The result of the marrow nail osteotomy was a complete correction of the shortening without any angulation (see illustration 154).

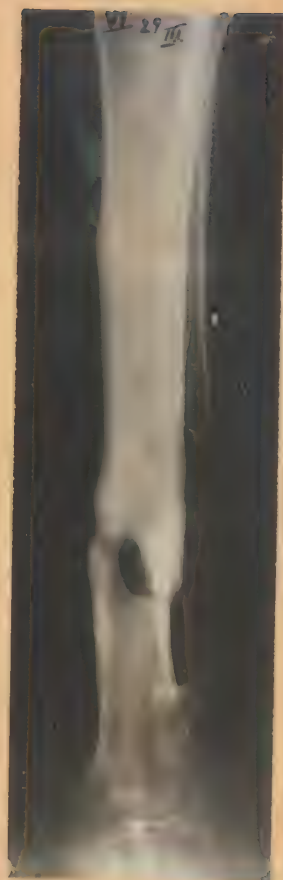
Further examples of marrow nailing for correction of dislocations are mentioned in the following chapter VII under the heading "osteotomy of infected fractures".



a



b



c

Illustration 153.

- a) 2 year old fracture of the lower leg of the patient G.D., healed with 4 cm. shortening,
- b) complete correction of the shortening by marrow nail osteotomy,
- c) after removal of the nails.



Illustration 154.

26 year old patient E.F. Example of the correction by marrow nail osteotomy of a 2 year old gunshot fracture of the femur, which had healed with shortening, angulation and lateral dislocation.

f. Lengthening by means of marrow nailing.

Only those cases are now left for discussion where there was originally a marked comminution of the fracture site and where the fragments healed together in a conglomeration with shortening. In these cases, the dislocation can be corrected only by a lengthening-osteotomy. The same often applies to oblique fractures with very steep fracture lines, which have healed with marked shortening.

It happens comparatively often that a bone is shorter than that of the other side. This may result from various causes: Either it has been too short since birth, or it has been shortened by a fracture or by an operation because of a tumor, or its growth has been impaired by a disease or even X-ray treatment of the epiphyseal line in childhood (A. BECK), or the corresponding bone of the other side has grown excessively by chronic inflammatory stimulation, etc. The numbers of these cases are certainly large, and it is frequently desirable to have the bone lengthened. Firstly, for cosmetic reasons, secondly there is an additional functional indication, though this is important only with the lower extremity. In the upper extremities, even considerable shortenings produce no marked functional disturbance, while even a few cm. shortening of the lower extremity does, as is well known. In spite of that, the operative lengthening has been an extremely rare operation previously (apart from the described false shortenings where there is dislocation, caused by a fracture of the femur healed in a bandy-leg or knock-knee position and this is corrected). This has been caused by the extraordinary difficulty of the operation, the often uncertain results and the long duration of the treatment. This operation is also often impossible because the bone tissue no longer has the power of regeneration necessary to fill the gap caused by the lengthening with new callus, or the soft parts, the connective tissue, the musculature, vessels, and nerves do not permit a greater lengthening. All this explains why lengthenings are made so rarely and why indications for functional reasons are made only in a few chosen cases, i.e. only the lower extremity is lengthened. In these cases the indication is all the more justified since dissimilar legs and dissimilar use of them inevitably cause early detrition of the joints, atrophies, arthroses, not only of the lower extremity but also of the pelvis and chiefly of the vertebral column.

For this reason, the attempts of solving the problem of lengthening, have been numerous. KIRSCHNER was the first to obtain satisfactory results through his idea of performing the lengthening in the sound bone, which still possesses unimpaired power of regeneration. KIRSCHNER cut the bone and applied powerful traction for a long time. The ordinary extension wires turned out to be too weak, so thick Steinmann-wires were used. In 1922, BIER demonstrated successful lengthening - operations on dwarfs. He cut the periosteum, corticalis, and marrow in one plane, but the bones were not drawn apart immediately, but were left standing beside one another so that the "metaplastic stimulation" produced by the bone fracture could have its full effect on the

surrounding tissue. Maybe this really was only the effect of the outflowing marrow (see chapter III). Then, traction-wires were inserted through the crests of the pelvis and through the condyles of the femur, and a long and intense traction was applied. Thus, the extension-weight of a 16 year old girl-dwarf, whose body weight was 30 kg, amounted to 20 kg per leg. The defect was admirably filled with bone tissue; the lengthening amounted to 4,5 cm. = 1/6 of the original length of the femur.

J. SCHULTZ, Riga, gave an excellent demonstration of this extension method. He gradually increased the extension so that a maximal weight of 20 kg and more is arrived at within 7 - 10 days. The periosteum in connection with the soft parts is gradually extended and, if the traction is increased slowly, even the osteogenic areas are hardly damaged. The powerful extension had to be retained for a long time. In no case could the leg be used earlier than after 5 months. Because of the hazard of a possible pseudarthrosis, the exercises of motion must be done with extreme caution. Due to these hazards and disadvantages, this lengthening operation has not been popular and is rarely performed.

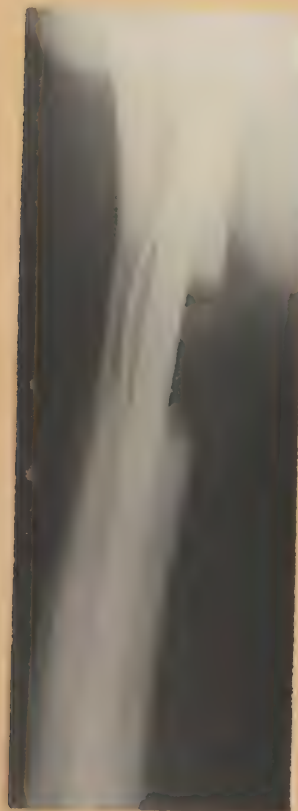
There are much better chances with the marrow nail! The disadvantages of an excessively long bed-rest and of such an enormous traction do not apply. The marrow nail is strong enough to resist the great forces which arise and to guarantee full ability of using the limb after a few weeks. Also with marrow nailing it takes many months to fill the large defect with new bone, but the patient need not stay in bed, but can be discharged from the hospital and carry on his trade.

Also in case of the extension-method, operative lengthenings are performed only on the femur, since it has considerably greater power of regeneration than the lower leg. With marrow nailing, there is an additional reason: a "stable osteosynthesis" may be obtained much easier with the femur than with the lower leg.

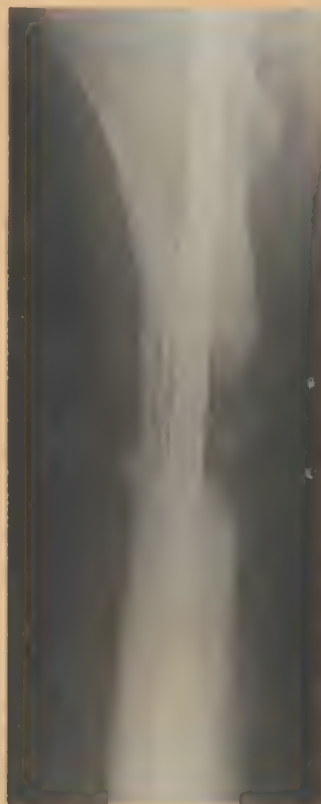
The author has mentioned two methods: In the one case, the fragments are kept apart by living bone, in the other case by dead bone. When selecting the place to cut the bone, one should prefer the middle of the bone for marrow nailing, because then the nail is held firmest in the two fragments, if this is not the place of the old fracture as well. Then it is suitable to saw the bone farther to the proximal side, in order to observe here also KIRSCHNER's principle of performing the lengthening-osteotomy on the sound bone. The question of whether the bone should be cut transversely or in a step-like manner, has been answered by KIRSCHNER in his lengthenings, in favor of transverse cutting, since the periosteum is better conserved then. For the same reason, the author thinks, according to his experience, the transverse or slightly oblique cutting more favorable in case of lengthening by means of marrow nailing.

We demonstrate these methods by two examples:

The 22 year old patient W.A. had a 4 month old gunshot fracture of the right femur. It was a long oblique fracture, which had healed in extension with 7 cm. shortening and good formation of callus. The fracture occupied the whole middle of the bone. There was no angulation. The bone was transversely cut with a saw proximal to the old fracture. Then intense traction was applied for about 15 minutes. During this period, a 5½ cm. long piece of the fibula of the same leg was resected together with the periosteum. After the gradual extension of the musculature, it was possible to insert the piece of the fibula in the bone defect which had been formed. A 2 mm thick Kirschner wire was introduced beside the guide rod through the marrow cavities of the proximal fragment of the fibula and of the distal fragment, and the end protruding from the trochanter-tip was bent down. Thereafter, the marrow nail was driven in as usual. The Kirschner wire holds the fibula piece extraordinarily firm, since it is only under stress in case of shearing off. It is impossible to remove the piece with the hand. Eight days later, the patient moved his leg without pain and used it a fortnight later, but then he felt pains in the hip-joint, the cause of which could not be determined. For this reason, he had to rest in bed for 4 weeks, afterwards he could use his leg again. No dislocation occurred, though callus was formed only slowly (see illustration 155).



a



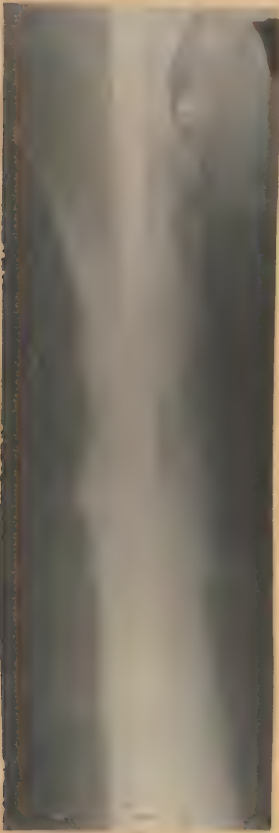
b

Illustration 155.

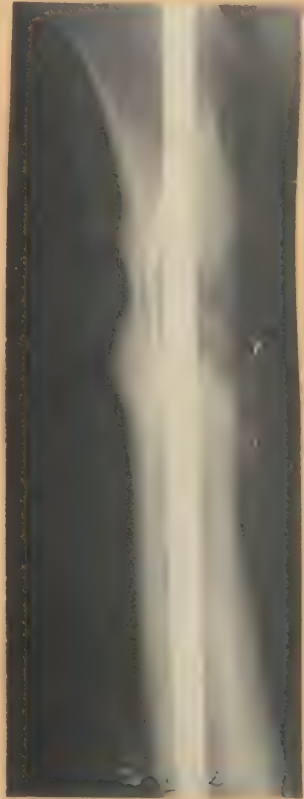
Lengthening osteotomy on the 22 year old patient N. A.

- a) After insertion of a tibia splinter covered with periosteum, which is held extraordinarily firm by a Kirschner wire
- b) Three months later, the defect has only partly been filled with callus.

In order to accelerate healing, a tibia splinter covered with periosteum was taken from the same side, and was pushed between the bluntly separated musculature and the osteotomy site. It was unnecessary to fix it specially, since the bone ends cannot move because of the marrow nail. It was sufficient to close the musculature above the splinter again by 2 catgut sutures. Two weeks after this intervention, the patient was able to walk around. The final success was excellent. The defect was completely filled with bone. The lengthening of $5\frac{1}{2}$ cm. fully persisted. There was no angulation (see illustration 156).



a



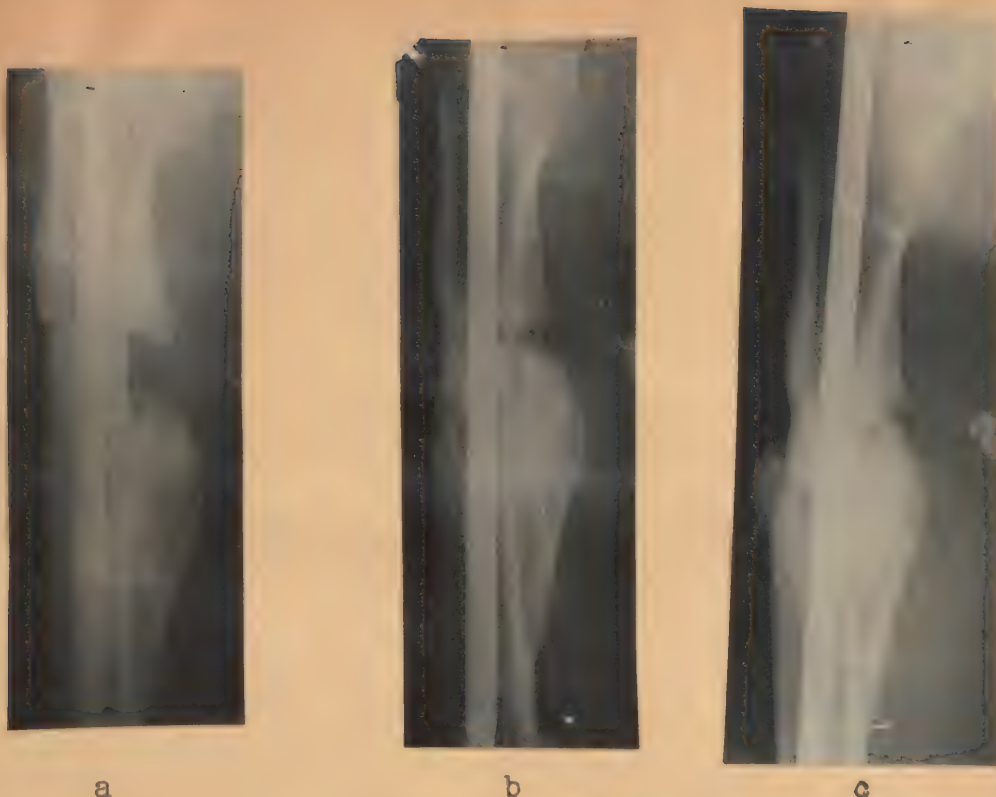
b

Illustration 156.

Lengthening osteotomy of illustration 155.

- a) After implantation of the tibia splinter covered with periosteum,
- b) the defect was completely filled with bone (X-ray taken 8 months after the operation for lengthening).

One year ago, the 25 year old patient H.R. sustained a pistol shot injury of the right thigh which caused a comminuted fracture, which healed in the plaster cast with 5 cm. shortening. There was a fistula. Four months after removal of the sequestrum and scraping out the fistula, a slightly oblique osteotomy was performed across the old fracture. After about 15 minutes of intense traction, a 6 cm. long boiled bone piece was inserted in the defect. The insertion was difficult and could be effected only by separation with powerful prying between the fracture ends and the bone piece partially inserted in the defect. Then, the marrow nail was driven through all 3 marrow cavities, and a very firm union was thus obtained. After the operation, the leg was 1 cm. longer than the other (see illustration 157).



a

b

c

Illustration 157.

Marrow nail lengthening - osteotomy.
One year old pistol shot fracture of
the femur of the 25 year old patient
H.R., healed with 5 cm. shortening.

- a) After slightly oblique cutting and
insertion of a 6 cm. long boiled
bone piece.
- b) 6 months later, the defect is filled
up almost completely with callus.
- c) Complete filling up of the defect
after 12 months.

The course of healing was without complications, the patient got up from bed after a fortnight and could use his leg at once. The formation of callus was slow even considering the size of the defect, but the patient was not hospitalized in that period and carried on his trade.

Marrow nail lengthening can be performed in considerably more exact amounts than extension-treatment. Of course, differences of 1 - 1½ cm. are of no importance.

During all lengthenings, no damages to nerves and vessels have been observed, though the extension was quite abrupt after all. Also in case of the considerable shortenings which were corrected in an equally sudden way by extension of a dislocation ad axin, no such disturbances occurred. An anesthesia in a region of the skin the size of a small hand above the patella which had appeared in one case after lengthening for 5½ cm., was not considered the consequence of the lengthening, but the direct consequence of a contusion of nerves during the operation. It disappeared 8 months later.

Such a marrow nail lengthening-osteotomy may also be performed with gradual lengthening. Then the intervention must be made in two operations. First, the bone is cut transversely with the counter-incision-saw through two comparatively small wounds. Then, a powerful wire-extension is applied for 7 - 10 days, as described in the discussion of extension treatment. On the 10th day, the outer wound is reopened and the marrow nail is inserted in one of the two ways. The disadvantage is the twofold operation. The author proposes to avoid this by the use of a twofold nail, which permits extension and thus lengthening, though no shortening. For the lengthening on persons with stunted growth, the last mentioned methods of gradual lengthening appear to be very useful, particularly since they cause only short interruptions of the ability of carrying on one's work. (Cosmetic lengthening).

HERZOG has demonstrated another method of marrow nail lengthening. To retain the distance of the bone ends, he does not insert bones, like the author, but obtains the same effect by metal bolts across the nail. HERZOG's experience is excellent. The hazard of infection is doubtlessly less great in this procedure. This is a great advantage, for it is always a considerable risk to use a bone splinter, as mentioned before. Particularly after gunshot fracture, the condition of the soft parts and of the bone is so seriously damaged that a lengthening-osteotomy is by no means indicated, especially if a serious infection or even gas-gangrene existed. The power of regeneration is so seriously reduced that an attempt at operation is irresponsible. Even the musculature is pale and decayed in those cases and does not permit any considerable extension. For this reason, only a shortening osteotomy of the sound leg may be considered.

D. Shortening osteotomy by means of marrow nails.

Also shortening osteotomies have been rather rarely performed previously. This was caused by the fact that the previous methods could not certainly guarantee the healing result, for, after a shortening, it is much more difficult to hold the bone ends in a favorable position in a plaster cast than a fresh fracture or a normal osteotomy, since all the soft parts and particularly the muscles become very slack. Thus, the protection, which the soft parts afford against a lateral dislocation, is almost completely missing, and the plaster cast fails for the same reason. Marrow nailing made it first possible to remove these disadvantages and render shortening-osteotomy a simple and certain operation.

Indications for operation are various and frequent. Marrow nail shortening of the sound leg in case of fractures healed with shortening was proposed and demonstrated by admirable examples by K. H. BAUER. These cases are particularly numerous after a war. If the legs differ considerably in length, an adaptation by orthopedic shoes is always only an insufficient expedient. The danger of such differences in length for legs, pelvis and vertebral column has been men-

tioned in the preceding section. BAUER proposed shortening even in case of vascular defects. BOEHLER performs marrow nail shortenings also in case of nerve defects caused by gunshots. He proposes this for defects of the ischiaticus as well, to make possible a suture of this nerve without tension. A leg without the ischiaticus functioning is useless, thus the shortening is absolutely justified. The sound leg may be shortened if necessary also in this case. E. GUENZ has proposed Henle's operation by means of marrow nailing. In his time, HENLE proposed to shorten both bones in case of an ischemic contraction of the forearm. However excellent this proposal may be theoretically, the practical results were unsatisfactory since, in the forearm, it is particularly difficult to make the two bones heal in a favorable position. For this reason one has preferred to shorten the wrist bones, which certainly is no ideal solution. The marrow nail has overcome these difficulties.

In case of pseudarthroses of one forearm bone, the author always shortens the other bone, he also shortens as often as he can in case of pseudarthroses of the upper arm.

Despite these various indications, the technique is absolutely uniform and typical. The bone is always cut in the middle, since there a stable marrow nail osteotomy is most certain. A transverse osteotomy is not indicated, since it is frequently not rotation-proof if the marrow nail is not absolutely firm. By no means, should it be performed on the forearm, as was particularly pointed out by GUENZ. At that place, the tendency to rotate at the osteotomy site is particularly great. The step-like osteotomy has no special advantages as contrasted to the oblique one, because the hazard of damaging the periosteum is greater with it. The author proceeds as follows: First, he arrives at the middle of the bone with a small incision. Then, the bone is obliquely cut with the described counter-incision-saw, and the bone ends are pushed out of the wound by bending the extremity at the osteotomy site. Then, the musculature together with the periosteum is pushed back at both ends as far as the intended shortening requires. The shortening is exactly checked with a boiled metal rule. Then, a corresponding piece is sawed off both bones in such a way that the new sawed surfaces of the bone ends are exactly parallel to the original sawed surface. Thereafter, the bones are rejoined by marrow nailing in the described way. If a femur is nailed, a guide rod is introduced into the proximal bone end from the wound, on the tip of which the nail is driven from the trochanter. The other bones are nailed without a rod.

We now mention some examples for marrow nail shortening osteotomy:

Two and a half years ago, the 25 year old patient O.K. sustained a fracture of the left femur caused by a shell-splinter, which healed with 9 cm. shortening. The leg was damaged by numerous scars, the knee and ankle joint were stiff. There were many small shell splinters around the old fracture. For this reason, a lengthening of this leg did not appear indicated, and an oblique shortening of the sound

leg by $7\frac{1}{2}$ cm. was made. The healing course was normal. The patient rose from bed 8 days later, but when he used his leg, he had the feeling that the leg was somewhat loose at the osteotomy site. Slight wobbling movements were possible, indeed. This was caused by the fact that, during this marked shortening, the whole middle part of the femur bone had to be removed and in that part the marrow cavity is narrow. The movement of the nail-point caused a stimulation for callus-formation, within the marrow cavity, which is distinctly recognizable in the X-ray (see illustration 158).

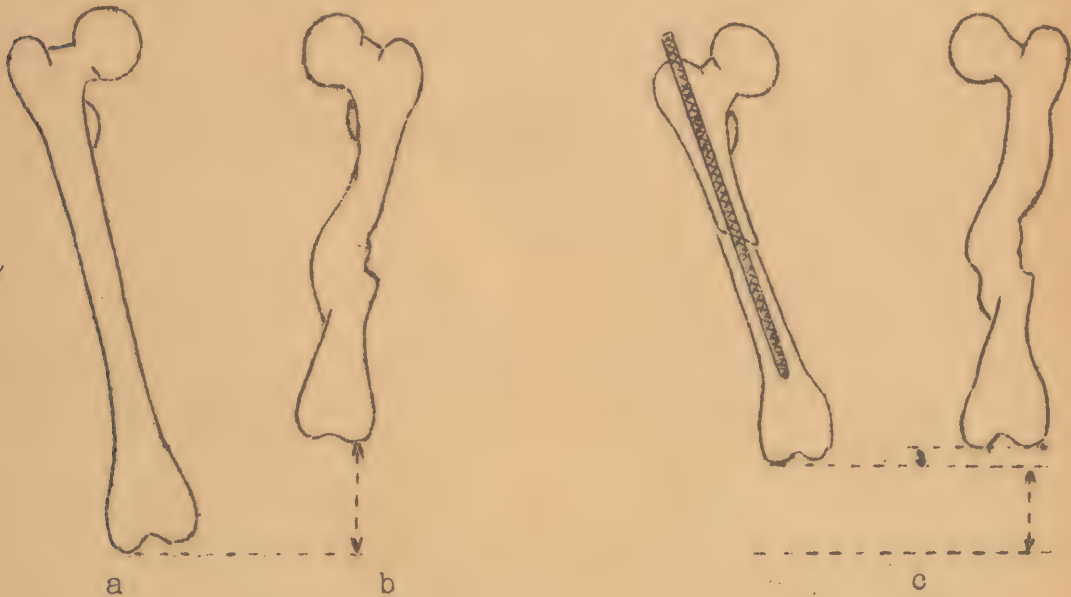


Illustration. 158.

Marrow nail shortening osteotomy of the sound leg after an old gunshot fracture of the left femur of the 25 year old patient O.K.

- a) left femur
- b) right femur before shortening,
- c) after $7\frac{1}{2}$ cm. shortening
- d) shortly after nailing
- e) marrow callus has formed around the point of the nail.

d

e

Even after 6 weeks, the looseness of the leg at the osteotomy site disappeared, but the patient still had no firm support on his leg. It turned out that there existed, in addition, a loose knee which certainly had not existed before. Experience has shown that the knee became loose in the first few weeks after the operation in case of all such extensive shortenings of the femur. 8-9 weeks later, this symptom always disappeared without any special treatment. This happened also in this case. This symptom may be probably explained by the fact that always a certain muscular tonus is necessary for the normal fixation in the knee-joint. If this tonus is suddenly completely absent, as in case of such a marked shortening, the symptom of the loose knee occurs. The musculature is gradually shortened, and its normal tonus is restored, and thus, the loose knee disappears. This is in accordance with an observation of HOHMANN, who found the symptoms of a loose knee in case of a weakness of the musc. vastus. It could be corrected by an operative shortening of the muscle.



Illustration 159.

Oblique osteotomy with $7\frac{1}{2}$ cm. shortening after healing. The same patient as represented in illustration 158. After the removal of the nail, at the end of a period of 12 months.

After 8 weeks, the patient was completely without complaints. The leg had become absolutely firm without an angulation, the joints could be moved freely (see illustration 159).

The 22 year old patient W.S. is mentioned as an example of a step-like shortening of the femur. Two years ago, he sustained a gunshot fracture of the right femur with 5 cm. shortening. The right knee and the left hip-joint were completely stiff. The right femur was shortened by 5 cm. The left femur was shortened in a step-like manner by 4 cm. The patient, who had been unable to walk before the operation and had to stay in bed for 2 years, could use his leg again afterwards. He got up from bed 4 weeks after the operation. The healing course was without complications. Also in this case, there existed the symptoms of a loose knee for some weeks. The marrow nail was removed after 6 months. The leg had become absolutely firm in the intended position (see illustration 160).

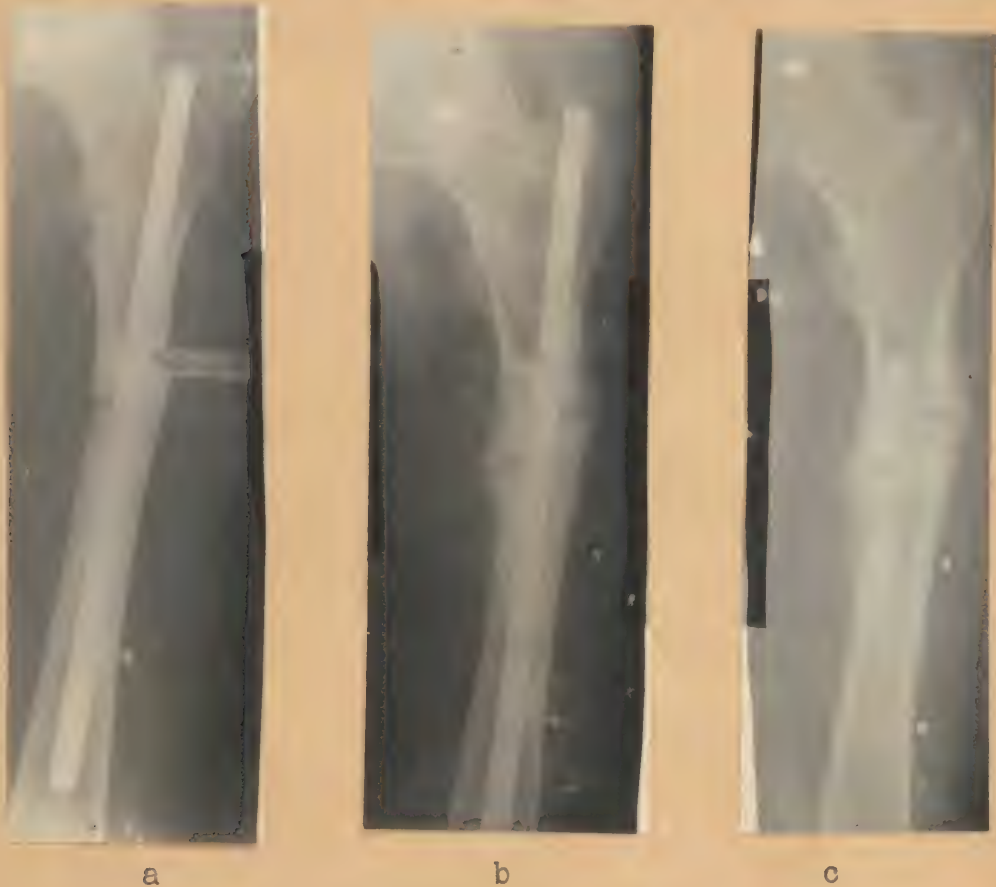


Illustration 160.

Step-like shortening osteotomy of the sound leg for 4 cm. of the 22 year old patient W.S. His right leg had been shortened for 5 cm. by a gunshot fracture of the femur.

- a) after the shortening
- b) five months later
- c) after removal of the nail 6 months later.

As an example of a shortening of the upper arm because of a 6 cm. long defect of the nervus radialis, we mention the 32 year old patient E.F., who had a 1 year old gunshot fracture of the right upper arm. The fracture had healed by firm bone with a lateral dislocation. The nervus radialis had a 6 cm. long defect at the mar-

gin of the lower third of the upper arm. The old fracture was left intact, in order to not complicate the operation unnecessarily and not to cause unnecessary necroses. So a 7 cm. long piece out of the middle of the bone was resected with an oblique section-plane. In addition, the bone ends were fixed to one another by a thick Kirschner wire, in order to prevent a separation of the fragments. The nail was driven in from the distal end at the beginning of the old fracture. Thus a straight 11 mm thick femur nail could be used (see illustration 161).

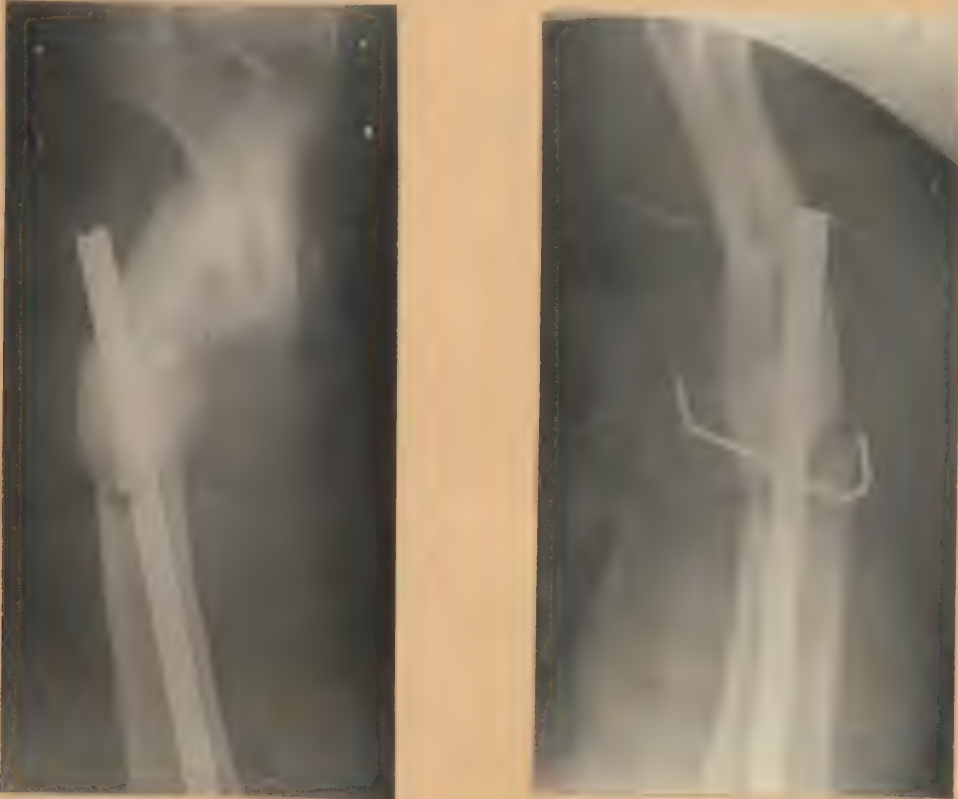


Illustration 161.

Shortening osteotomy of the upper arm with a 6 cm. long defect of the nervus radialis. There was a 1 year old gunshot fracture of the upper arm, healed with a lateral dislocation (32 year old patient E.F.) Condition after marrow nail osteotomy.

The osteotomy healed by firm bone in the intended position. After 4 weeks the nerve was sutured, which was possible without any tension. Despite this, a later examination after $1\frac{1}{4}$ years showed no success. Of course, it is quite possible to perform both operations, osteotomy and nerve suture simultaneously, but the principle of operating in two stages permits making exposure smaller and thus lessens the hazard of infection.

If the sound leg is shortened, man as a whole becomes shorter. Some people say that this might cause mental depression. Doubtlessly everybody endeavours to appear as tall as possible. For this reason, the wild tribes wear a high coiffure, the ladies wear high heels, kings a crown. We meet this tendency even among animals,

and know that an animal is not impressed by the bulk of another animal, but only by its height. The antlers of the stag too have a similar importance. On the other hand, the sign of humility and servility is the "self-diminution" the bow, lifting one's hat, etc. Thus, the idea that mental depression might develop, can be understood. The author, however, could not find the slightest clue for any such depression with his "shortened" patients, though some persons refused the proposed intervention. At any rate, one never will disturb these deep-rooted sentiments without conclusive reason and will shorten the lower extremity only with exact indications.

With the forearm, one may also consider a shortening in the form of the above mentioned Henle-operation. Its indication is the inability to use the arm or a considerable reduction in the use of the hand and forearm as the consequence of an ischemic contraction. As a matter of fact, amazing success may be obtained by this method. As regards operative technique, one of the 5 methods described in the section on marrow nailing of pseudarthroses should be used. As examples, we mention two cases of E. GUENTZ.

Fifteen year old school-boy. Ischemic contraction and paralysis of the ulnar nerve by a gunshot through the right shoulder with injury of the arteria subclavia and suture of it. Since because of the markedly increased sensitivity no reduction apparatus or bothersome bandages were tolerated, the forearm was shortened by 3 cm. During the nailing, the fragments were easily reduced. On 16 August 1943 operation, plaster cast for 8 days. Immediately free movability of pronation and supination of the hand. The claw-like position of the fingers decreased considerably. The active movements of the fingers improved a good deal. X-ray control on 11 November showed complete bone healing, the nails were removed on 1 February 1944.

A 20 year old man had sustained, at the age of 1½ years, a supracondylar fracture of the humerus with consecutive ischemic contraction, which was in right-angle flexion position and excessive supination and could be used only for rough holding of some objects. Now the patient desired to be able to use his hand well while working on a card-index. Since the X-ray showed that the wrist bones were well developed and no nerve defects existed, so that a possible function could be expected, a shortening osteotomy was performed. Three cm. resection during transverse osteotomy, which turned out to be unfavorable, because the bones kept their distance and the period from the beginning of February to November of the same year was necessary to produce complete bone healing. The hand was brought in a slight pronation and could be extended up to the straight direction after removal of the plaster cast, which had been applied for 11 days. It was difficult to form a fist with opposition, since the flexor profundus was very weak. For this reason, a transplantation of the brachioradialis to the profundus-sinews of the 2nd and 3rd fingers was made. The patient is now quite able to work on his card-index and to use his fingers in this work. The nails were removed one year after the operation.

E. Marrow nailing of fractures with delayed healing or no healing (Pseudarthroses).

The best definition of the term "pseudarthrosis" was given by GULEKE and is based on the roentgenological observation of the closing of both marrow cavities without any bony bridging over of the fracture cleft. This implies that the existing condition is final and no further development can be expected without special measures. Quite the opposite is the condition of the delayed healing of a fracture, where a bony bridging over is still possible.

As has been described in chapter III, there are 2 causes of pseudarthroses:

1. deficient regeneration of callus within the fracture cleft, and
2. the wrong differentiation of this callus due to mechanical causes, so that no bony bridging over occurs.

The second cause is by considerable the more frequent.

Deficient formation of callus may have either general or local causes. The general causes are: marasmus, diabetes, scurvy, tuberculosis, lues, etc. Of course these causes will be treated casually, i.e. to try to control the original disease. As the author was able to show (chapter III) it is possible to stimulate intensely the formation of callus by nails of strong chemical effect. The clinical use of this principle, particularly by STOTZ - Giessen and MAATZ - Kiel, has been described before.

The number of these pseudarthroses however, is very small indeed, as mentioned above, as contrasted to those mechanically caused. In these cases, the pseudarthrosis is not caused by no or insufficient formation of callus or by absence of bone formation. On the contrary, we have observed that sufficient callus is formed in most cases, but that there is a cleft through this callus. With this cause, marrow nailing appears to be the method of choice during causal treatment. The nail absorbs all injurious tensions and for the first time guarantees an undisturbed development to the callus, since there was no remedy before to eliminate the injurious minute movements. Thus it is the best prophylactic against pseudarthroses as well. Thus, the author has been informed of no case of a pseudarthrosis after successful marrow nailing. If pseudarthrosis did occur after marrow nailing, the cause was always an insufficient mechanical solidity of the nail. A marrow nailing of the forearm is mentioned as an example. A resection of the bone ends had been performed in some other hospital on a 23 year old patient because of a pseudarthrosis after gunshot fracture of both bones. This resection, however, had been performed not obliquely but transversely so that the marrow nail was not rotation-proof. Thus, a pseudarthrosis occurred despite enormous formation of new bone (see illustration 162).



Illustration 162.

Pseudarthrosis after marrow nailing, after resection of radius and ulna. The junction was not rotation proof, because the resection had been performed transversely instead of obliquely.

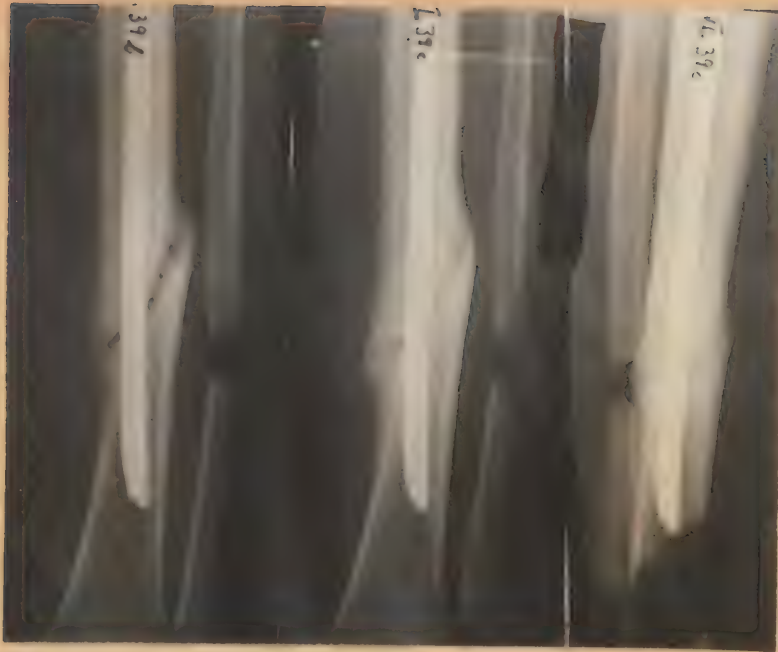
Generally speaking, such pseudarthroses after marrow nailing are quite rare indeed. Even slight jaggedness of a fresh transverse fracture is sufficient to clinch the fracture planes together and to make the marrow nailing rotation-proof, particularly since the muscle traction still presses the teeth on each other. This does not apply to exact resections, where 2 completely level planes are confronted, and the muscular traction on the forearm is no longer so effective because of the removal of the bone fragments. The pseudarthrosis is a final condition. Any treatment with medicines, hormonoids, or hormones is useless. For this reason, one does not read of any convincing proof for a successful treatment in a critical examination of the respective literature.

During any treatment of pseudarthroses, the very first thing to do is to start the halted process of callus formation going again. Then one

must see to it, that now the germination of the callus in the fracture cleft is mechanically protected and thus forms bone and not connective tissue (see chapter III).

In case of delayed healing of fractures, the latter alone will do, theoretically considered, viz. the insertion of a marrow nail. As an example, we refer again to the case in chapter III. This case was a fracture of the tibia, which showed no bone callus in the X-ray even after 8 weeks in a plaster-cast. Marrow nailing was possible without opening the fracture, though with enlargement of the fracture cleft for $1\frac{1}{2}$ cm. After the marrow nailing, the formation of bone was so intense, that the whole fracture cleft, $1\frac{1}{2}$ cm. wide, was filled with bone.

We mention the 36 year old patient E.P. as one more example of delayed healing of a bone fracture. He sustained a simple fracture of the left lower leg by a traffic-accident. The fracture had not become firm during 6 months of treatment in plaster. The fracture was absolutely freely movable. The X-ray showed no callus at all, only resorption was manifest at the bone ends. On the other hand, the marrow cavities were not yet closed by bone. For this reason, it was quite possible to insert a marrow nail as in case of a simple fracture (see illustration 163).



a

b

Illustration 163.

Delayed healing of a fracture of the lower leg of the 36 year old patient E.P. after an accident.

- a) Condition after closed marrow nailing and resection of the fibula.
- b) Condition 3 months after marrow nailing.

The fibula was resected at the same time. The patient could get out of bed 8 days after the operation. Then, the bridging over by bone took 2 months. Thereafter, the fracture was completely consolidated by bone in a favorable position.

The 44 year old patient H.S. was an example for the femur. He sustained a fracture of the femur in a traffic accident. After 8 weeks of plaster cast treatment, the roentgenogram showed no callus at all. This was, however, not the only indication for marrow nailing, but the unsatisfactory position of the fracture as well. The marrow nail was inserted, though the form and the position of the fracture were not particularly suitable for doing so. The fracture was located much to the distal side, in addition, a large third fragment had broken out. The marrow nailing was performed, operatively from the first, since only an operative reduction appeared possible. During the operation no callus was observed. After the operation, an infection set in with fever and marked suppuration, which lasted 8 weeks. The patient got out of bed 6 weeks after the operation. The fracture healed with consolidation by bone. Eight weeks later the wounds had completely healed.

Marrow nailing practically always stimulates the formation of callus (see chapter III). With a pseudarthrosis, there is, in addition to this, the piercing of the bone caps

and the drilling open of the marrow cavities. This usually requires a considerable display of force and energy, so that the progress of the callus mechanism is guaranteed. For this reason, marrow nailing usually will do even in case of pseudarthroses, though one sometimes likes to add a moderate splintering up of the fracture end according to KIRSCHNER, by slightly opening the bone ends with a chisel. One must be cautious, however, not to force open the marrow cavity too much. The nail may lose its firm position altogether, such as at the distal end of the femur (see illustration 164).

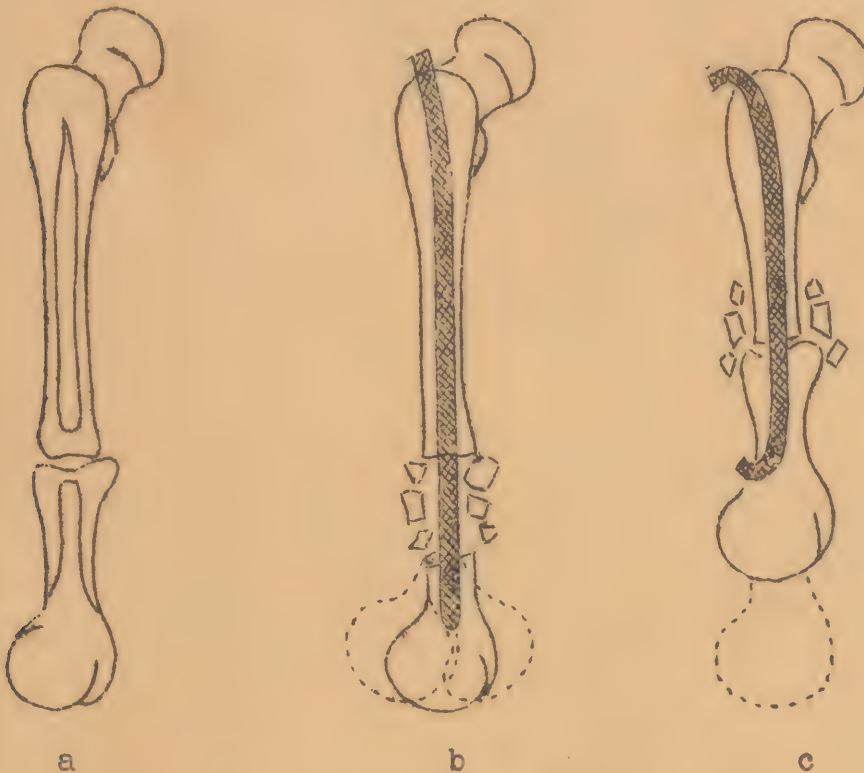


Illustration 164.

Diagram of a femur pseudarthrosis in the lower third. By splintering the distal fracture end, the marrow nail would lose all support.

In such a case, one would restrict oneself to a moderate splintering of 1 cm. length or even desist from it altogether, since any considerable shortening of the lower extremity must be avoided at all costs. Also here, a freshening of the bone surface itself by removal of the connective tissue is usually sufficient. In this case, the author recommends Luer's rongeurs, with which the bone ends are bitten off, as it were. In the majority of pseudarthroses of the lower extremity, he even did not remove the connective tissue at all and only drilled the marrow cavities open.

With a small number of marrow nailings of fractures with delayed healing, the intervention is possible without any operative opening of the fracture, viz., if there is no considerable dislocation and the marrow cavities approximately confront one another. In other cases old dislocations exist

which can be removed but seldom. Then, one must use an osteoclast in most cases. The author has used osteoclasts of RIZOLI, ALSSBERG and PHELPS-GOCHT and found them all suitable. (see illustration 165).

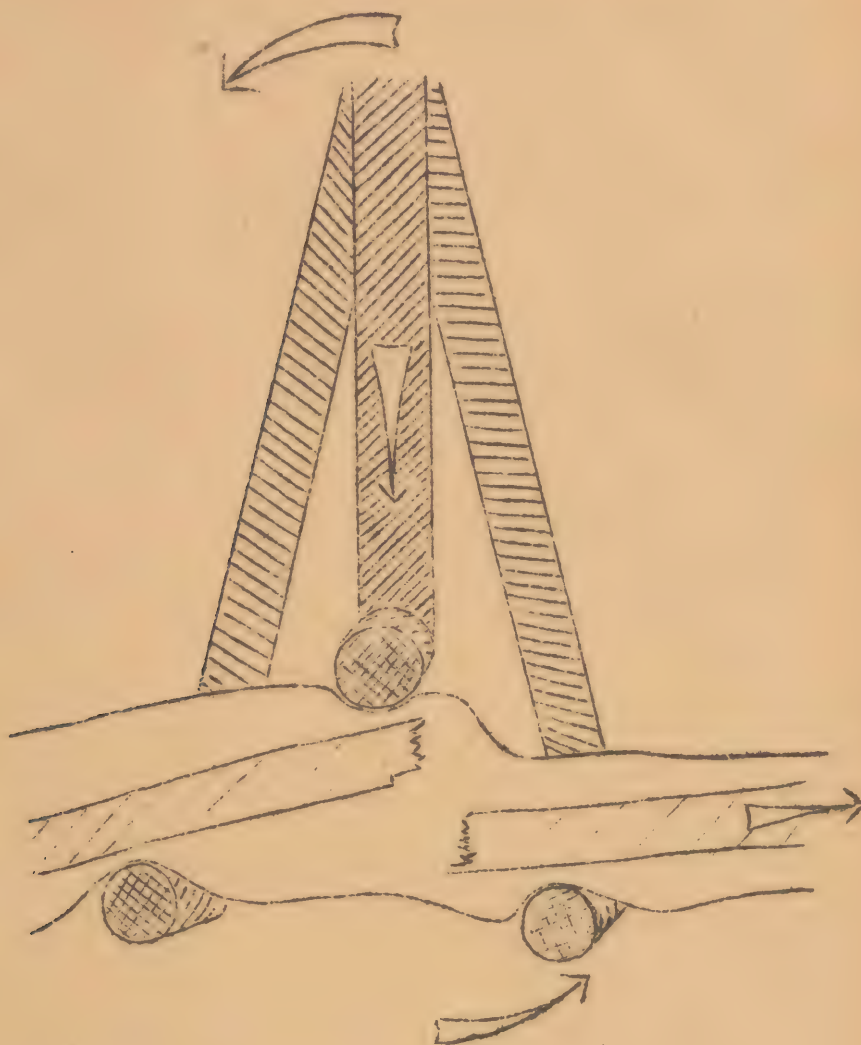


Illustration 165.

Reduction of an old dislocation with an osteoclast according to PHELPS-GOCHT for the percutaneous marrow nailing in the case of a delayed healing of a fracture.

It is by no means advisable to try for any length of time to enforce a closed marrow nailing in a case like that. This only leads to injuries of the extremity and loss of time, and eventually one has to open the fracture after all.

Furthermore, it is by no means advisable to nail a fully developed pseudarthrosis without opening the fracture cleft. The marrow nail is not constructed to pierce the bone lids of the marrow cavities. One frequently has observed that it is extraordinarily hard to drill the marrow cavity open with a pointed awl, even if the bone caps seemed to be very thin in the X-ray. So one easily sees that the less sharp points of the nails can by no means pierce the bone by simply hammering them through. Intense hammering will therefore lead in such

a case only to a bending of the nail and a shattering of the tissue of the extremity. This more or less marked, absolutely useless, injury, can be avoided from the first by beginning at once the inevitable operative opening of the pseudarthrosis. The operative technique on the upper and on the lower extremity is difficult in principle.

I. Marrow nailing of pseudarthroses of the lower extremity.

On principle, the technique here is in details the same as that of open marrow nailing of the respective bones described in this chapter, particularly since it is often not even necessary to remove the connective tissue from the fracture cleft as mentioned before. Also with regard to a possible necessary freshening of the fracture ends, the most important things have been mentioned, so that examples of the various forms of pseudarthroses can be mentioned at once.

The pseudarthrosis of the femur neck is suitably and successfully treated with the femur neck nail and thus it is not within the scope of this book. As mentioned in chapter III, one may, in particular cases, give a more favorable inclination to the fracture cleft by performing a subtrochanteric osteotomy. This so-called PAUEL-operation can be performed to advantage with marrow nails. It is described in the following section of this chapter.

The subtrochanteric pseudarthrosis of the femur must be treated with the Y-shaped nail (see chapter V), since the simple marrow nail cannot sufficiently be fixed because of the width of the marrow cavity in the trochanter mass. Even in these cases, the Y-shaped nail permits a good fixation, since it is fixed the whole length of the femur neck by its transverse portion.

We mention the example of the 36 year old patient W.L. Two and a half years ago, he sustained a gunshot-fracture of the right femur, which, treated with a plaster cast, led to a sub-trochanteric pseudarthrosis. Three attempts had been made to heal the pseudarthrosis: transplantation of a splinter, Beck's drilling and Kirschner's splintering, without any success. The knee and ankle-joint were stiffened. The stiffening of adjacent joints, which was caused by the long fixation, considerably complicates the healing of pseudarthroses. It causes extraordinary long lever-arms, which increase many times the forces effective in the fracture cleft. A movable joint may protect the fracture from motion, a stiff one necessarily transfers every passive movement, as described in the example of the elbow-joint (see illustration 166).

In this particular case, the pseudarthrosis cleft was opened. The cleft appeared to be a joint-cleft with smooth joint-planes. Marrow nailing was performed without any freshening of these planes. The healing course was normal. A fortnight after the operation, the patient could get out of bed, to which he had been confined for $2\frac{1}{2}$ years. A fort-

night later, he used his leg. The pseudarthrosis healed with firm bone in a favorable position (see illustration 167).

The 23 year old patient W.W. had a pseudarthrosis of the middle of the femur after gunshot fracture. It had persisted for 2 years. During this period, the patient had a plaster cast. Since a fistula existed, none of the usual operations of pseudarthrosis was performed. Despite the fistula the marrow nail was inserted. This procedure is described in detail in the following chapter. The healing course was without complications. Seven weeks later, the patient could get out of bed. The extremely movable pseudarthrosis had become fixed by bone. The operation lasted 7 minutes (see illustration 168).

The 45 year old patient J. Sch. had a 1½ year old pseudarthrosis of the femur after gunshot fracture. A wire suture had been made without any success. There was a fistula too.

The case was rather unfavorable for marrow nailing, because the pseudarthrosis was located far to the distal end. The knee, however, had already become completely stiff, so that a simple nail could be used, which was fixed by introducing it deeply into the knee-joint. The healing course was normal. Even 3 weeks after the marrow nailing, the patient could get out of bed (see illustration 169).

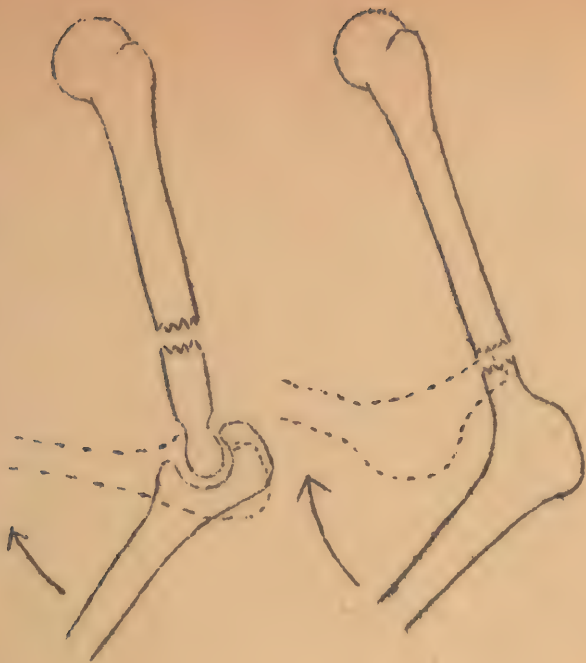


Illustration 166.

Diagram of the transfer of a passive movement of the forearm on a fracture of the upper arm and a stiff elbow-joint. Movable joint does not transfer this movement to the fracture site.

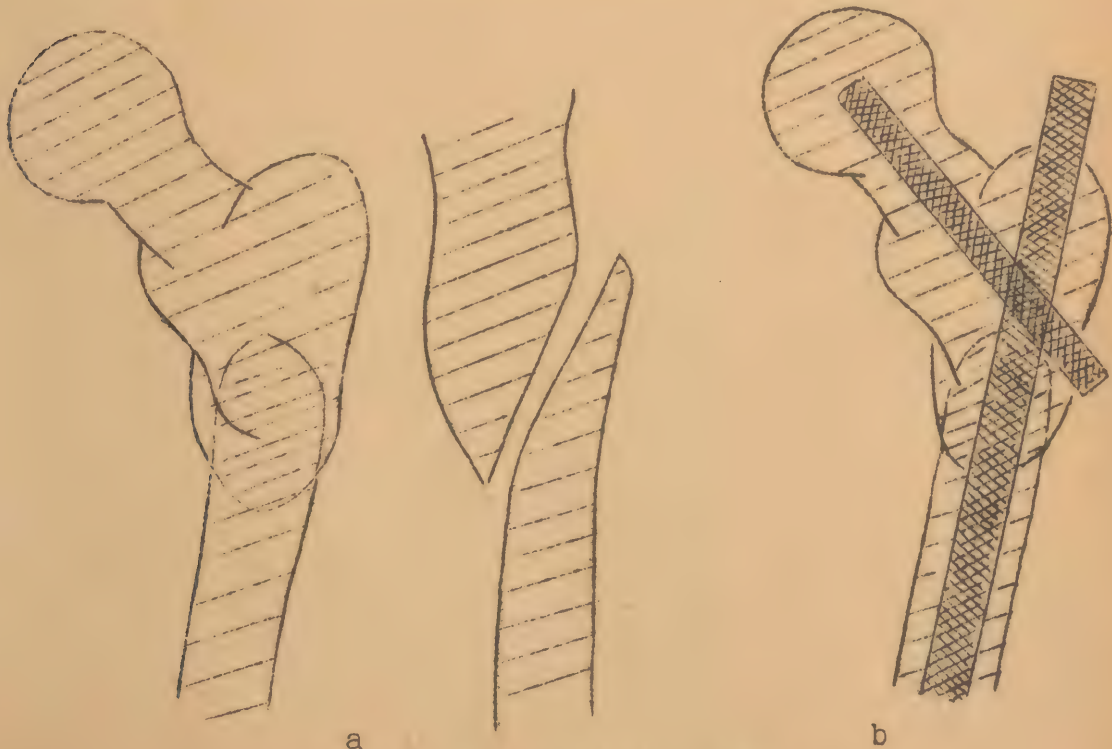
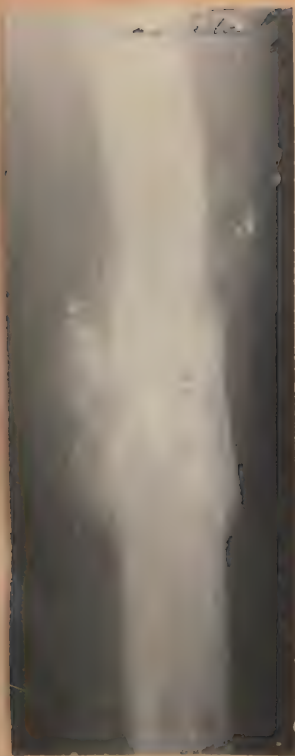


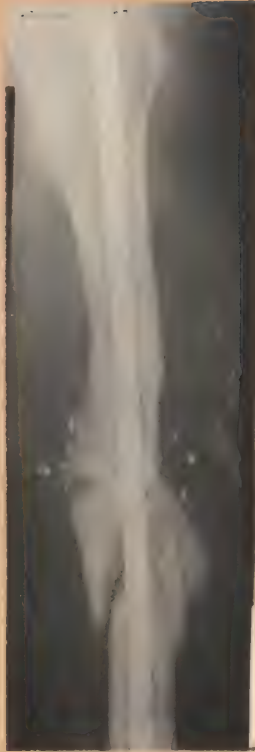
Illustration 167.

Two and a half year old subtrochanteric pseudarthrosis of the 36 year old patient W.L. after gunshot fracture.

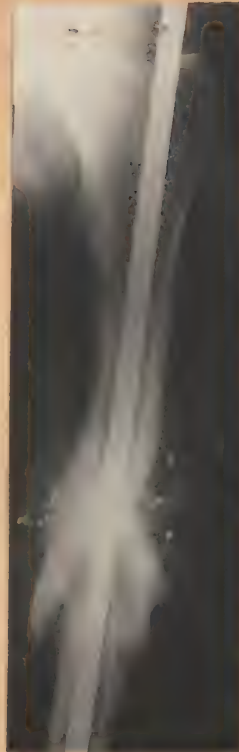
- a) before marrow nailing
- b) after marrow nailing.



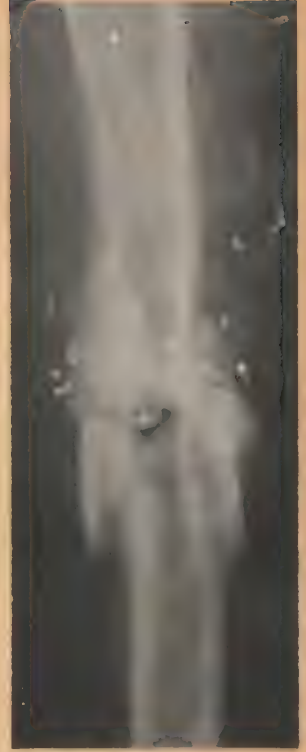
a



b



c

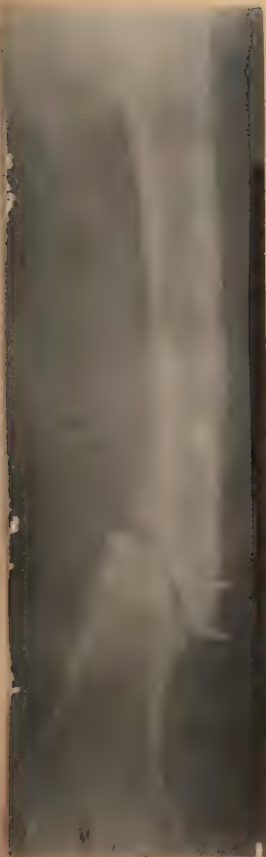


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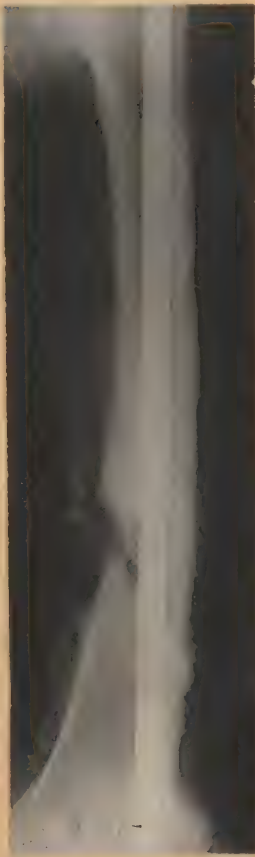
Illustration 168.

Very movable 2 year old pseudarthrosis of the middle of the femur after gunshot fracture of the 23 year old patient W. W.

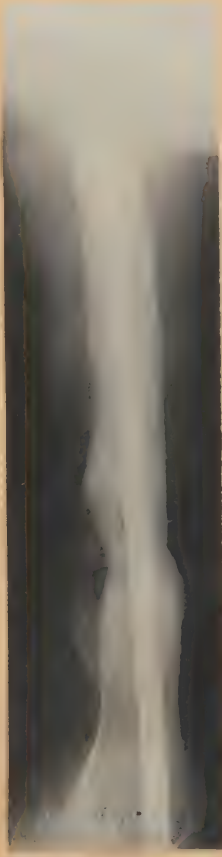
- a) before marrow nailing
- b) immediately after marrow nailing
- c) after 4 months.
- d) after removal of the nail after 6 months.



a



b



c

Illustration 169.

Pseudarthrosis in the distal third of the femur after gunshot fracture. Patient J. Sch. age 45 years. The pseudarthrosis was 1½ year old.

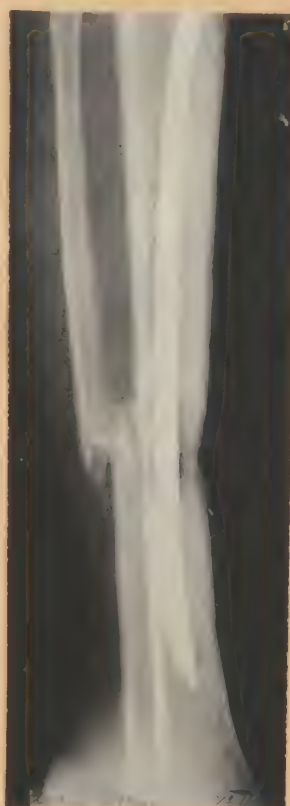
- a) before marrow nailing
- b) immediately after marrow nailing
- c) six months after marrow nailing

At last, we mention some pseudarthroses of the lower leg.

The patient J. M. age 52, had a 3 year old pseudarthrosis with fistula of the right lower leg after an accident. The course after the marrow nailing was normal. The pseudarthrosis was fixed without shortening in a favorable position, since only one nail was inserted and no connective tissue was removed. Even the fistula closed, though only 4 weeks after the removal of the nail (see illustration 170).



a



b

Illustration 170.

Three year old pseudarthrosis of the lower leg in the upper third. Patient J.M., age 52.

- a) immediately after marrow nailing
- b) after several months.

The 25 year old patient W. H. had a 1½ year old pseudarthrosis, which had been operated several times without success. In this case, it was possible to freshen the pseudarthrosis, since a shortening of 2-3 cm. did not matter, because the other leg had been amputated. So a step-like freshening in the form of a double step was made with a bow-saw. The healing course was without complications. Since the fracture was located far to the proximal end, the patient was allowed to get out of bed and use his leg only 10 weeks later. The fracture healed in a favorable position with a good fixation by bone (see illustration 171).



a

b

c

Illustration 171.

One and a half year old pseudarthrosis of the lower leg after gunshot fracture of the 25 year old patient W. H.

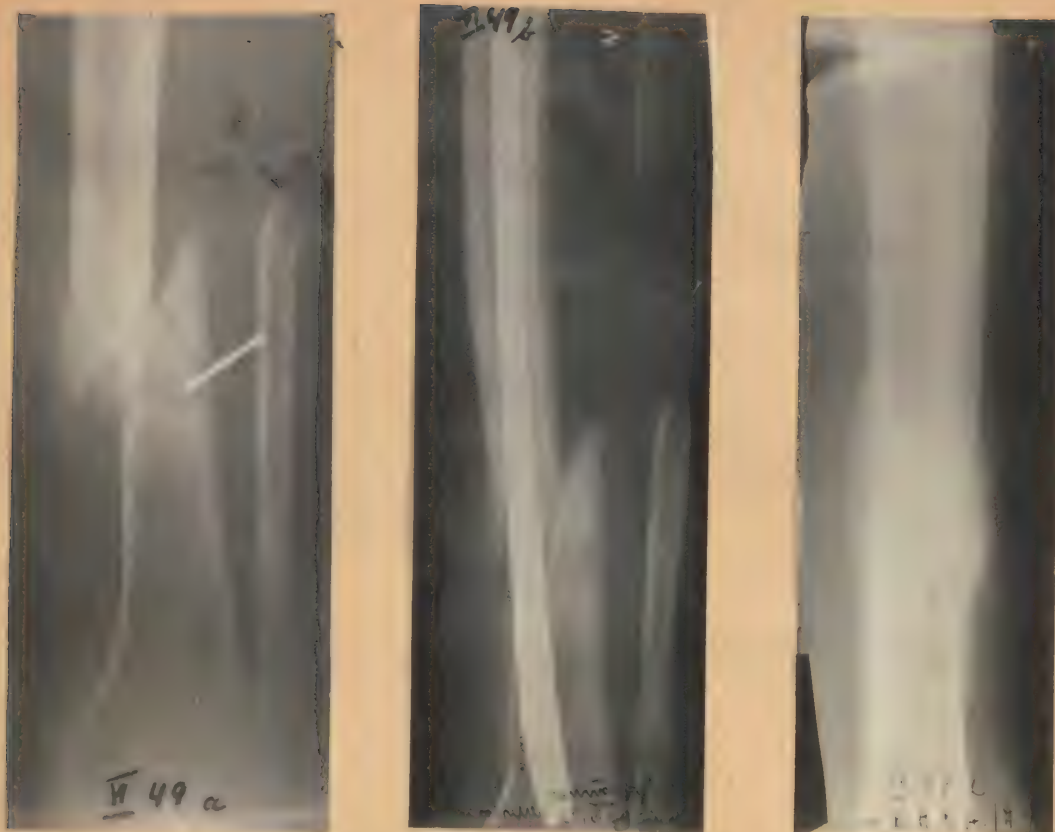
a) before the operation

b) after freshening in the form of a double step, which was possible because of an amputation of the other leg, and marrow nailing

c) after extraction of the nail.

The 36 year old patient J.S. had a one year old pseudarthrosis below the middle of the tibia, which had been caused by an accident. There existed a fistula. Several unsuccessful operations had been performed, the last a drilling during which the drill broke. During osteotomy no callus was found, the drill was removed. The healing course was normal. The pseudarthrosis was fixed by bone in a favorable position. Because of persistent intense suppuration, the patient could use his leg only 5 months later. After 6 months the nail was extracted (see illustration 172).

The 18 year old patient G.K. had a year old, intensely suppurating pseudarthrosis in the distal third of the tibia after an accident. In case of many of these pseudarthroses near the ankle joint with marked suppuration, the upper and lower foot joints become completely stiffened and are often even fixed by bone. In these cases, it is possible to nail the pseudarthrosis from the distal end with temporary separation of the skin of the sole of the foot. This is the technique of the arthrodesis of the foot-joint, as described in chapter VIII. In most cases, a straight femur nail was inserted, though this often turned out unfavorably. This is no genuine marrow nailing, but part of the nail sticks only in the spongiosal bone of the distal end of the



a

b

c

Illustration 172.

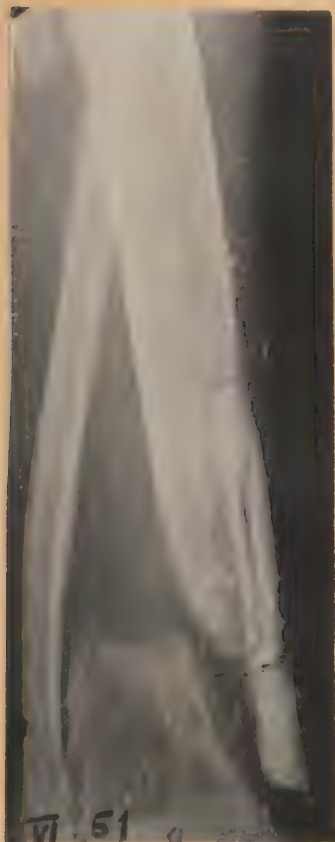
One year old pseudarthrosis of the tibia below the middle, of the 36 year old patient J.S.

- a) before marrow nailing
- b) after marrow nailing
- c) after extraction of the nail, 6 months later.

tibia, of the talus and of the calcaneus. The nails will work loose at this place, so a second nail must often be driven in beside the first. Persistent infections occurred. In one case, a fatal infection set in because of the instability of the osteotomy, as described before in chapter IV. For this reason, it is suitable to use instead of the femur marrow nail the foot-joint arthrodesis nail with a broad head, which is described in chapter VIII.

In the present case, a long femur nail was used. High fever set in and persisted for weeks, and several times abscesses had to be incised in the area surrounding the pseudarthrosis. At last, however, the pseudarthrosis became fixed by bone and the fistulae healed, so that the patient could use his leg 7 months later. After 5 more weeks, the nail was removed (see illustration 173).

Illustration 174 shows one more case of this kind. It is the case of the 23 year old patient H. B., who had a 3 year old pseudarthrosis with fistulae, which had been unsuccessfully treated with drillings and plastics of bonesplinter.



a



b

c



d

Illustration 174.

Three year old pseudarthrosis of the lower leg in the central third with stiffening of the upper and lower foot joints. Several unsuccessful operations one of them a plastic of bone-splinter.

- a) before marrow nailing
- b) after marrow nailing
- c) after 6 months
- d) after extraction of the nail, 7 months later.

Despite the fistulae, marrow nailing was performed from the distal direction. Also in this case, several abscesses occurred, which necessitated frequent incision, so that this

patient too, could use his leg only after 5 months. It is true, he suffered from abdominal typhoid in this period too. The final result, however, was healing by bone (see illustration 174).

In some of these cases, a second marrow nail was driven in to restore the stability, so that the nails were linked to each other through their slits (see chapter V).

With the 42 year old patient K. J., a pseudarthrosis with fistulae had existed after gunshot fracture in the lower third of the lower leg with a 3 cm. long defect. There had been five operations without any success. The upper and lower foot joints were stiffened by bone. The marrow nail was inserted from the distal direction. Also in this case, many abscesses appeared which had to be incised. Then, the lower leg bent at the pseudarthrosis site in the nature of a bandy leg, nor was the osteotomy site rotation-proof any longer. Thereupon, a second nail was driven in, and the pseudarthrosis became fixed by bone. The patient could use his leg however, only 8 months later (see illustration 175).

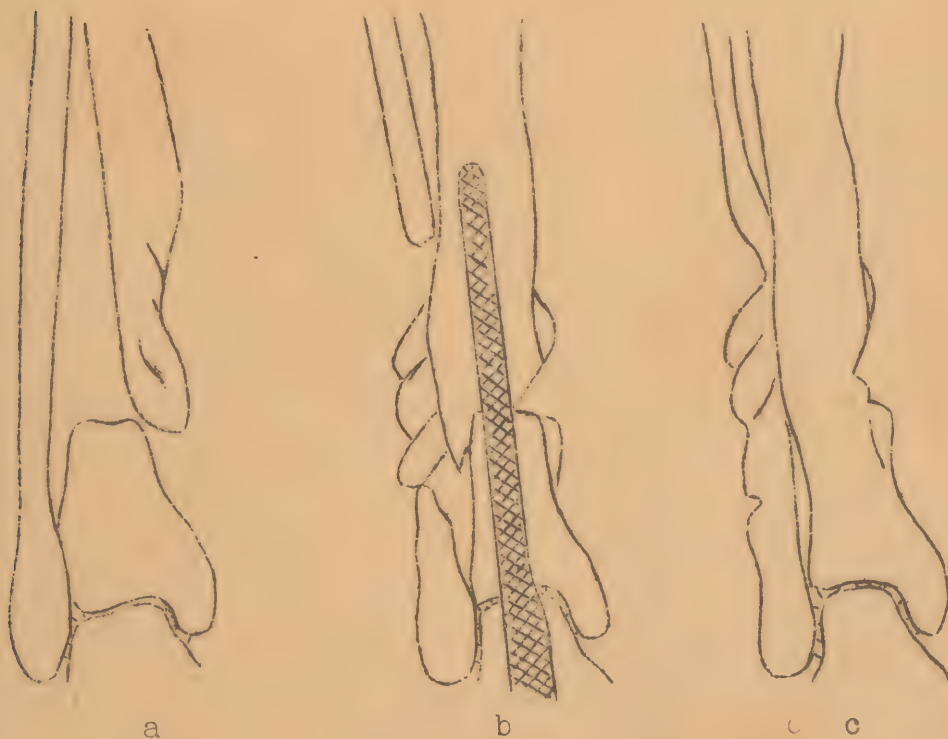


Illustration 175.

Pseudarthrosis of the lower third of the tibia of the 42 year old patient K.J. after gunshot fracture, 2 years old.

- a) before marrow nailing
- b) after marrow nailing
- c) healing by bone, 8 months later.

In this case, the fibula had been resected during the preceding operations. It was resected this time as well, since the fibula is generally resected during all osteotomies of the lower leg, as described before.

II. Marrow nailing of pseudarthroses of the upper extremity.

In the lower extremity, the pressure of the musculature and in walking the weight of the body as well are strong enough to guarantee a sufficient stability of the osteosynthesis and to press the fragments against each other when, some weeks later, the marrow nail is loosened by resorption around the nail. In the upper extremity, this is not true any more in case of most pseudarthroses. The considerably weaker musculature is usually so much weakened by prolonged fixation in a plaster cast, by operations and infection that it is no longer capable of pressing the fragments against each other along the marrow nail to a sufficient degree, particularly since the bone is often shortened, in addition, during the operation. On the contrary, the weight of the distal part of the extremity draws the fragments wide apart. HAEBLER has observed this even in case of a fresh fracture of the upper arm (see illustration 176).

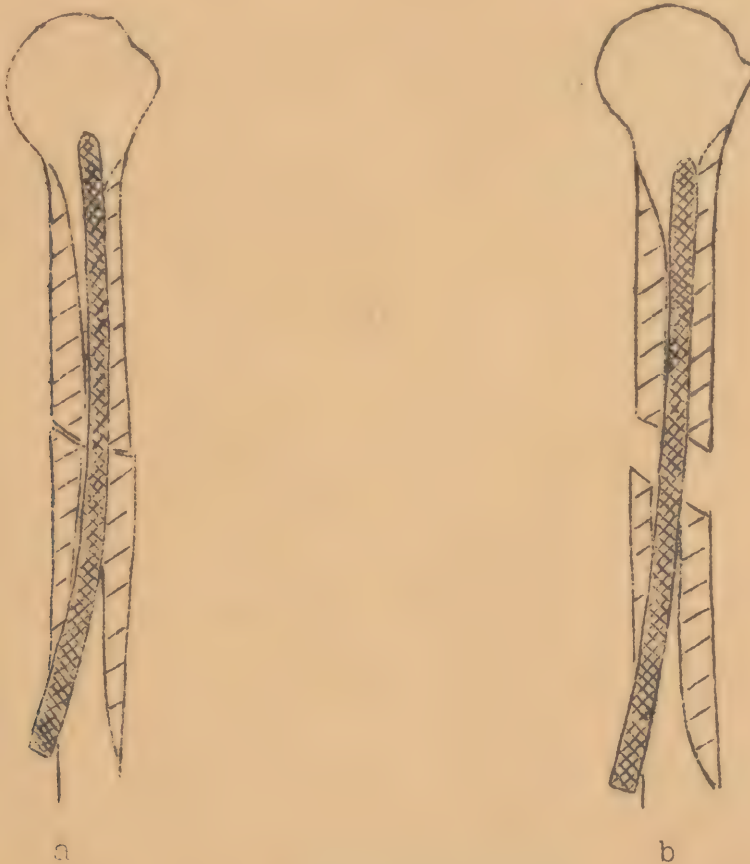


Illustration 176.

Marrow nailing of a pseudarthrosis of the upper arm.

- a) immediately after the operation
- b) after 2 weeks. The ends are wide apart through the pressure of the tissue and the weight of the extremity. Even if the gap is comparatively small, no bridging over by bone will occur.

This is shown by the case of the 21 year old J.B. Here, the pseudarthrosis cleft was so small that it seemed justified to try a simple marrow nailing first, particularly since

the cleft ran in an oblique direction (see illustration 177).

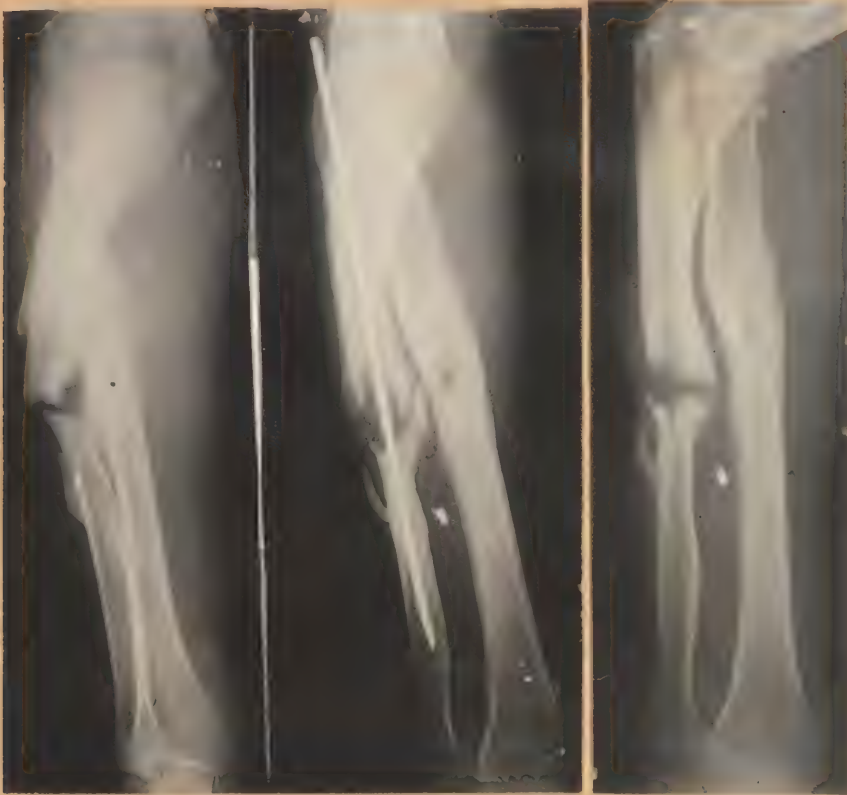


Illustration 177.

- One year old pseudarthrosis of the ulna after shell splinter injury, with the 21 year old patient J.B.
- a) before marrow nailing
 - b) afterwards; despite favorable conditions a complete failure has occurred
 - c) after extraction of the nail, 3 months later. No bridging over by bone

Despite the favorable conditions of this case the result was a complete failure. It is absolutely wrong to treat pseudarthroses of the upper extremity, particularly of the forearm by marrow nailing in this way. It is, however, equally wrong to make the nail responsible for the failure. The cause is rather the described condition of the musculature, and the best evidence for the correctness of this opinion is the fact that all pseudarthroses were fixed without any exception, if the tendency of the fragments to separate was removed. There are five methods by which this tendency may be overcome:

1. The resection site is resected in a step-like manner. It is always advisable to make a freshening or even extensive resection on the upper extremity, since a shortening does not matter, as described in the beginning of this chapter. The steps are joined by a thick Kirschner wire drilled through the bone in a direction transverse to that of the nail. The ends of the wire are bent down.

Disadvantages: In case of marked suppuration the wire cuts, so the steps of the resection must be made large enough. The method can be used only with the upper arm. To remove the contrivance, both the place where the nail was driven in and the 2 places where the wire was bent down must be reopened.

2. Special springs according to MAATZ. MAATZ replaces the lost "drawing" effect of the muscles, as it were, by wire springs, which are inserted in the marrow cavity beside the nail. The ends of the helical springs are provided with small metal hooks, which are fastened to the holes in the corticalis of the two fragments, at a great distance from the osteotomy site. The hooks are broad lest they cut the bone in the presence of an infection.

Disadvantages: The hooks are hard to insert. Two more operative incisions must be made to insert them. It is even more difficult to find them again. That is practically possible only with a high frequency metal searcher such as developed by KUENTSCHER. In addition, it is usually hard to apply the wire traction in the marrow cavity. The springs break easily and are hard to extract because of cicatrization.

3. The bending down of the nail according to the author. This is the most simple method, but practical only on the humerus and ulna. It will do at all events, as shown by experience, since it is sufficient to hold a fracture together by shortening of a bone. With the ulna, a simple marrow nail is driven in at the proc. styloideus, so far through the proximal fragment that its point protrudes from the olecranon. Then, a femur nail is pushed over each end of the nail till it touches the bone with the assistant pressing the forearm firmly together in the sense of a shortening, and the operator bends the protruding ends of the ulna nail down to an acute angle by using the femur nails as long levers. This is an immensely powerful union, which does not cut the bone very much, even in case of marked suppuration, because of the thickness of the nail. It may be used with the upper arm as well. Then the nail is inserted as usual from the distal side, but, at the same time, a marrow nail is driven in from the other typical place proximally at the outside of the upper arm (see chapter V), though only a few centimeters deep, because it serves only as a guide rod for the point of the other nail. One may also proceed the other way from the proximal to the distal side. When a sufficiently large hole is drilled above the upper arm, the point of the nail appears in this hole. The nail is bent down in the same way as the ulna nail.

Disadvantages: In order to remove the marrow nail, two wounds must be reopened. However, it is easy to locate the nail. One of the bent down ends must be cut then with a powerful pair of forceps, or it is broken by bending it back and forth.

4. The marrow screw according to the author. The nail is thickened at its head and lies with this thickening in the distal end of the ulna, where the marrow cavity is always broad as contrasted to the middle. At its point, it

is provided with a nut, which is screwed in with a long wrench from the direction of the upper arm. As the marrow cavity is broad at that place too, a strong nut finds room in it. By tightening the nut, the osteotomy seam is strongly pressed together. The advantage of this method as contrasted to the two mentioned before is that the whole mechanism of the osteosynthesis is located within the marrow cavity and thus, an important principle of marrow nailing (chapter II) is fully observed. The screw may also be readjusted.

Disadvantages: Two incisions are necessary to remove the contrivance, though only those usual for marrow nailing of the ulna (chapter V).

5. The olive-wire according to POHL. POHL has described thick wires with an olive-like bulge at the end of the caliber of the marrow nail used. The end in the form of an olive is inserted first, then the nail. Thereafter a pierced olive is pushed on the wire and pressed into the marrow cavity by means of a screw or a helical spring. The osteotomy seam is pressed together by a screw, or, if necessary, with insertion of a helical spring. The advantage is that the same wound is used both for insertion and removal of the contrivance and for the nail and that the compression starts from the marrow cavity.

Disadvantages: The insertion of the contrivance is sometimes not easy technically.

The results of these 5 different methods are approximately of the same value. The author did not observe any failure in any of them. With the helical spring, it was sometimes necessary to readjust the wire. With the bending down method healing appeared to be most prompt. This is the only method which really effects a rotation-proof union. The wires are not rotation-proof themselves. They prevent rotation only by pressing the bone ends firmly on each other. For this reason, the bone ends must be shaped accordingly. So it is once more emphasized that only oblique or even step-like osteotomy sections are practical; with the upper arm also to take advantage of the splintering of the bone ends in such a manner that the splinters remain in connection with the periosteum and musculature.

These five methods are first schematically represented in illustration 178 and then practically described by some examples.

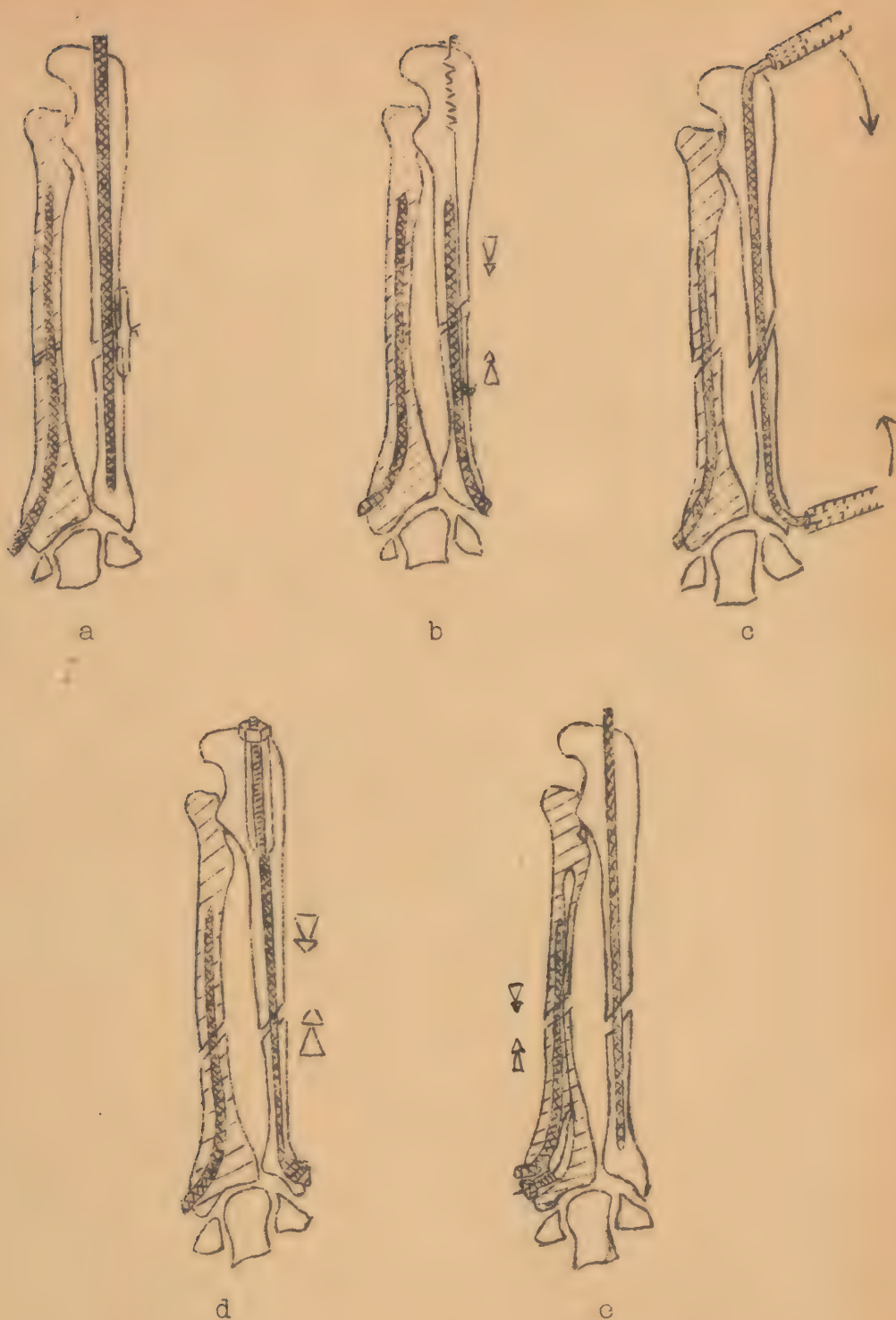


Illustration 178.

Schematic representation of the 5 methods for shortening of the separation of the bone ends during marrow nail osteotomy of the forearm.

- a) transverse wire according to KUENTSCHER
- b) helical wire according to MATZ
- c) bending down of the marrow nail according to KUENTSCHER
- d) marrow screw according to KUENTSCHER
- e) olive wire according to POHL.

Examples for pseudarthroses of the upper arm.

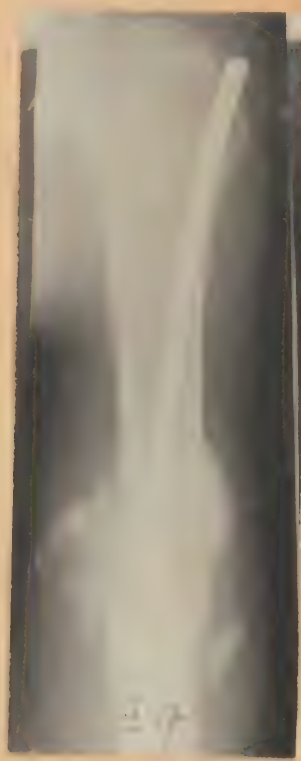
The 36 year old O.O. had a year old pseudarthrosis in the middle upper arm after injury by a bazooka (Panzerfaust). Method 1 was used. No splint was applied, but active exercises were started 8 days later. Even within 6 weeks enough callus had been formed. The fracture was fixed in an ideal position. After 3 months the nail was extracted (see illustration 179).



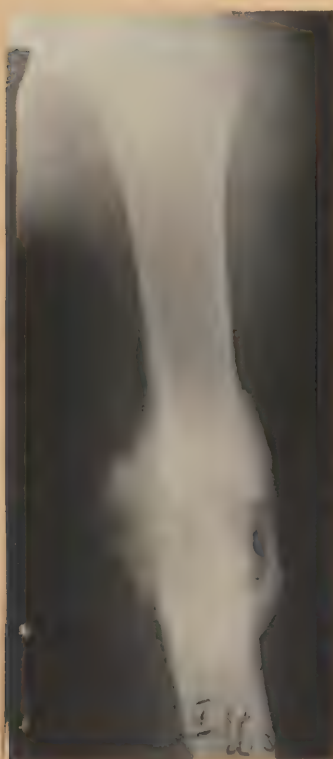
a



b



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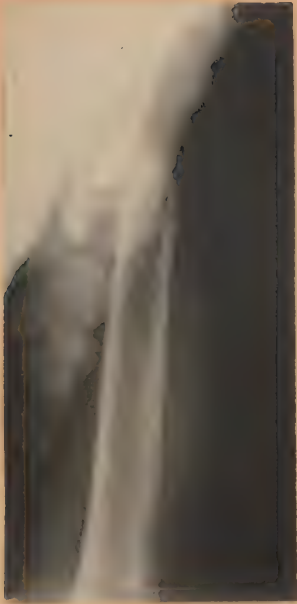


d

Illustration 179.

One year old pseudarthrosis of the upper arm of the 36 year old patient O. O. after injury by a bazooka.

- a) before the operation
- b) after marrow nailing according to method 1 (KUENTSCHER)
- c) after six weeks
- d) after extraction of the nail 3 months later.

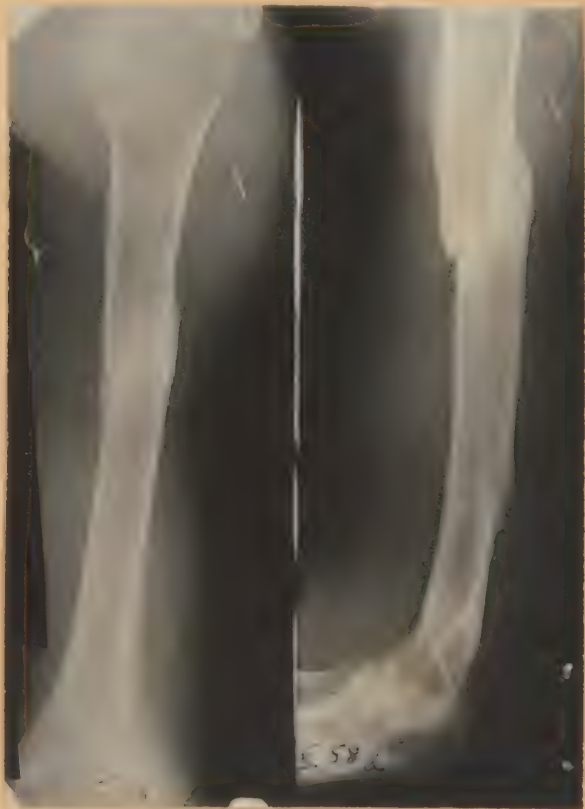


a

The case of the 50 year old patient O.T. is an example of marrow nailing according to method 2. The pseudarthrosis of the middle of the left upper arm had been caused by an accident and had been operated 16 times without any success, which had caused a shortening of 9 cm. The pseudarthrosis had persisted through 8 years. After the operation, an abduction splint was applied for 6 weeks for security. The healing was delayed, but after 12 weeks sufficient callus had formed. The pseudarthrosis was fixed by bone. Shoulder and elbow joint were not limited in motion (see illustration 180).



b



c

Illustration 180.

Eight year old pseudarthrosis of the left upper arm after accident of the 50 year old O.T. which had been operated 16 times in vain.

- a) before marrow nailing
- b) after marrow nailing according to method 2 (M.L.T.Z)
- c) subsequent to extraction of the nail after 4 months.

The 41 year old patient P.V. had a 2 year old pseudarthrosis located high in the upper arm with marked suppuration after a gunshot fracture. Method # 3 was used. Because of the suppuration, an abduction splint was applied for 8 weeks. After 6 weeks, a sequestrum the size of a hazel-nut was removed. At the same time, the wire spring had to be tightened, since the small hook had cut owing to the suppuration. The application of the spring traction at the head of the nail was effected by a broad calotte, in order to prevent safely any cutting into the massive tuberculum majus. The final result was excellent. The pseudarthrosis was fixed by bone in a favorable position. The fistulae closed (see illustration 181).

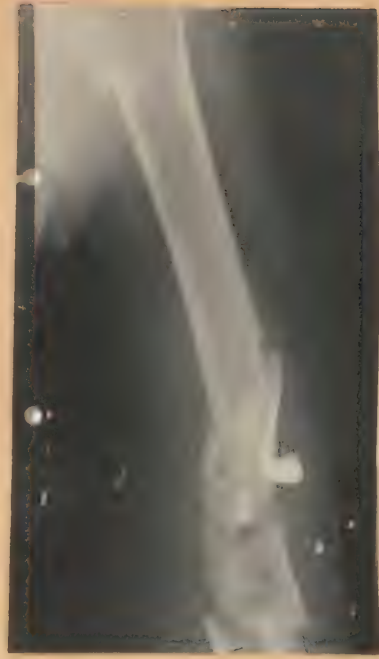


Illustration 181.

Pseudarthrosis of the upper third of the upper arm of the 41 year old patient P.V. after gunshot fracture, 2 years old, with pronounced suppuration.

- a) after marrow nailing according to method 3 (MAATZ)
- b) after 8 months
- c) after removal of the nail after 12 months.

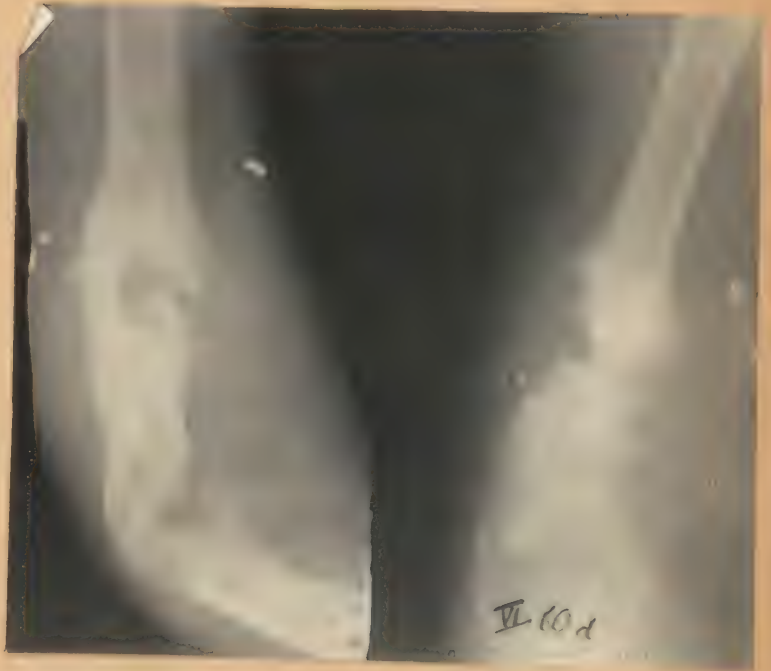
The 33 year old patient H.B. had a pseudarthrosis of the middle of the upper arm after an accident. It had been unsuccessfully treated $1\frac{1}{2}$ years in a plaster cast and by 3 operations. Method # 3 was applied. The healing course was without complications. No splint was applied. The result was absolutely firm union by bone in a favorable position with only slight reduction of movability of the joints, which had been caused by the preceding treatment and considerably improved after the marrow nailing, so that exercise of movement could be started within 3 weeks after the operation (see illustration 182).



a



b



c

Illustration 182.

Pseudarthrosis of the middle of the upper arm of the 33 year old patient H.B. after accident, 1 $\frac{1}{4}$ year old.

a) before the operation

b) after 6 weeks

c) after extraction of the nail, after 9 months.

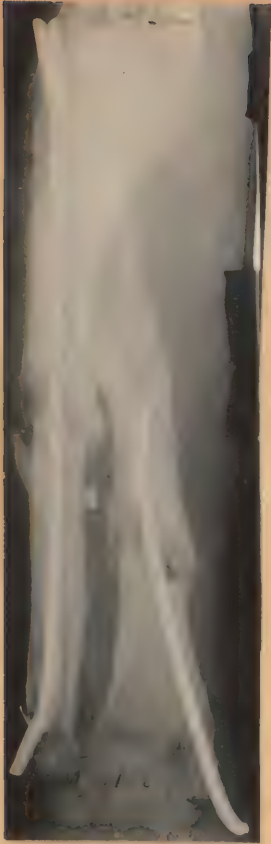
Examples for pseudarthroses of the forearm.

Because of the special mechanical conditions, the healing of pseudarthroses of the forearm is particularly difficult. The fracture ends are subject to a great tendency to rotation. In addition, the bones of the forearm have only a small power of regeneration, they form only a little callus. Unsuitable fixation will promptly damage the complicated system of muscles and sinews.

The implantation of large bone splinters according to LEXER requires a long period of fixation, which is not applicable in cases of pseudarthroses with fistulae. A particularly long protective term must be observed in this case. As shown by experience, even then the splinters do not heal in, because the tissue is damaged forever by the shock wave of the modern missiles (see also chapter VII). In addition, there are today the consequences of a long malnutrition which considerably reduce the power of resistance of the organism against infections. This corresponds to experience also in other fields of surgery. Thus, according to the latest publications of FROMME, the rate of infections after hernia operations has increased enormously. The author considers this from the first and uses no bone splinters, because the success of the operation is void, if infection develops (EDITOR'S NOTE: Here KUENZSCHER speaks of conditions current since the end of the war). This does not apply to the marrow nail, it is true. Even cases with fistulae can be nailed, as described in the following chapter. If there is a defect of one bone of the forearm, the other bone is shortened the same amount. If a pseudarthrosis of both bones exists, both bones are shortened as much as necessary to freshen the pseudarthrosis and to perform oblique sections. Since the bones of the forearm are liable to splinter, the use of a chisel is warned against.

First we wish to describe the further course of the case represented in illustration 177, in which the ulna pseudarthrosis did not heal through simple marrow nailing. The forearm was shortened for 3 cm. by oblique osteotomy. Also the ulna was shortened at the osteotomy site and the osteotomy site compressed, by use of a spring (method 1). Thereupon, the pseudarthrosis healed; (see illustration 183).

The 20 year old patient U.W. had a 3 cm. long defect of the left radius after shell splinter injury. The pseudarthrosis had existed for $2\frac{1}{2}$ years. The ulna was shortened by 6 cm. and an ordinary nail inserted. An olive-wire was attached to the radius. The pseudarthrosis healed by bone in a favorable position. Ten months later, the nail was removed.



a



b

Illustration 183.

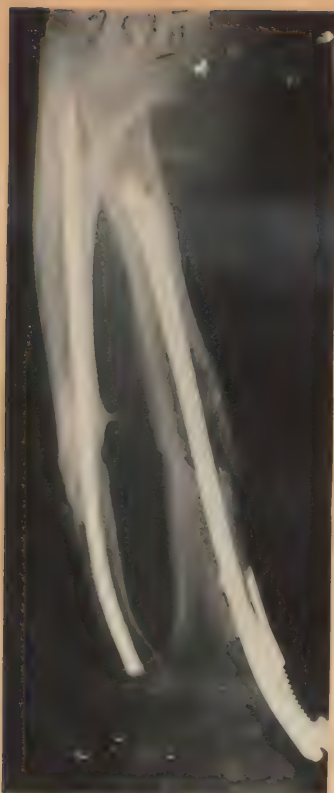
The same ulna pseudarthrosis as represented in illustration 177.

- a) two months after marrow nailing
- b) after extraction of the nail after six months.

The 38 year old patient W. S. had a 1½ year old pseudarthrosis, after shell splinter injury. The radius was shortened by 3 cm. and method # 5 used with the radius. The result was healing (see illustration 184).



184a



b



c

Illustration 184.

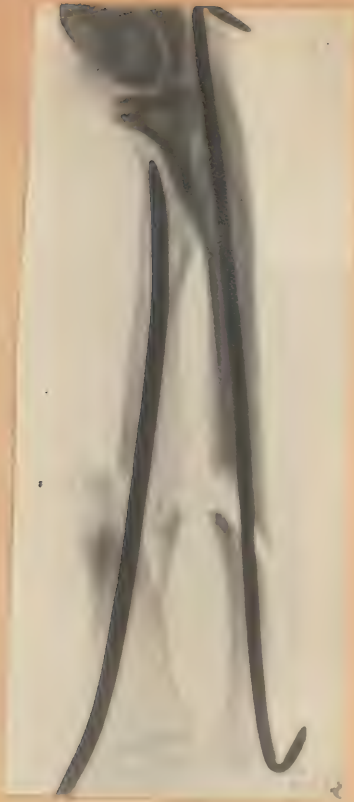
One and a half year old pseudarthrosis of the ulna after shell splinter injury of the 38 year old patient W.S.

- a) before marrow nailing
- b) after 2 months, radius shortened by 3 cm. and an olive wire inserted in the radius.
- c) after extraction of the nail, 6 months later.



185a

The 28 year old patient P.G. had suffered for $1\frac{1}{2}$ years from a 2 cm. long defect of the radius with synostosis between radius and ulna at the pseudarthrosis site following a gunshot fracture. The ulna was shortened by 4 cm. and fixed in its position by bending the nail down. The synostosis was removed. The pseudarthrosis healed firm by bone in a favorable position (see illustration 185).



b



c

Illustration 185.

Defect pseudarthrosis of the radius of the 28 year old patient P.G.

- a) before marrow nailing
- b) after resection of the ulna for 4 cm. union of the ulna by bending down the ends of the nail (method # 2)
- c) after removal of the nail after 6 months.



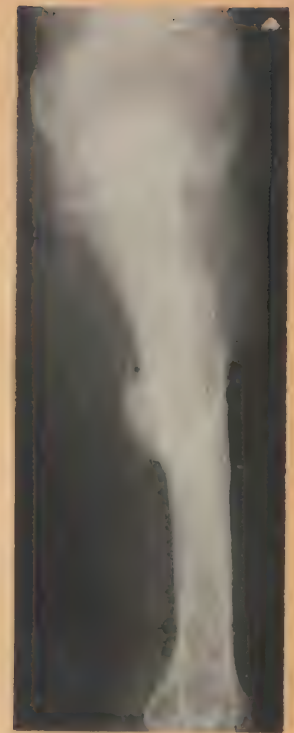
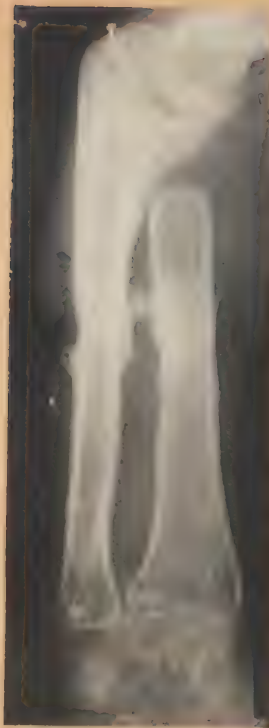
The marrow nail was removed after 6 months by straightening the bent end at the olecranon and extracting the nail distally.

With the 25 year old patient W.P., the forearm was in an almost rectangular position at the margin of the proximal third. The ulna had firmly healed by bone, but was eburnized at the place of fracture and there was no longer any marrow cavity. The radius showed a pseudarthrosis (see illustration 186.)

186a



b



c

Illustration 186.

Pseudarthrosis of the radius. Ulna of the 25 year old patient W.P. healed with marked angulation.

- a) before marrow nailing
- b) after resection of the ulna by 7 cm.
- c) after extraction of the nails after 6 months. The radius head was resected.

Example for the method described under # 2. The eburnizing area of the ulna was resected for an extent of 7 cm. but the extra callus masses were left on both bones, so that the forearm looks in the X-ray immediately after the operation as if the osteotomy site were already bridged over by bone. Despite the marked shortening of the ulna by 7 cm., the forearm was not much shortened by the osteotomy, as the operation put the arm in a straight position and thus, the seeming shortening was removed.

The 21 year old patient J.B. had a pseudarthrosis of the left radius after shell splinter injury for 2 years. Because of the closeness to the wrist, the pseudarthrosis itself was not suitable for marrow nailing, since the marrow nail could not be fixed in the short distal fragment (see chapter V). Even in this case, the principle of shortening was observed, the ulna shortened by marrow nailing by 3 cm. and an olive wire inserted. Then, the proximal fragment of the radius was freshened and stuck into the distal fragment, which had been splintered before. A dorsal plaster splint was applied, as in case of a fracture of the radius. During all other osteotomies of the upper arm and forearm described above, no plaster cast

whatsoever was used. Only in times where a fever existed, an additional fixation of the joints was made during the period of the fever. An infection of the wound, with high fever, set in, and that surprisingly 6 weeks after the operation. Because of wrong bending of the nail before the nailing, the tip of the nail lay close to the joint-cleft of the elbow, and pain and a hematoma were caused in the elbow-joint. Thereupon, the nail was immediately extracted and both, the place where the nail had been driven in and the osteotomy wound at the ulna were opened. Then, the fever decreased and the symptoms on the part of the joint disappeared. The joint remained freely movable. Because of the early extraction of the nail however, the radius pseudarthrosis was not healed, but an additional pseudarthrosis was formed now at the resection site of the ulna by the separation of the bone ends. (See illustration 187).

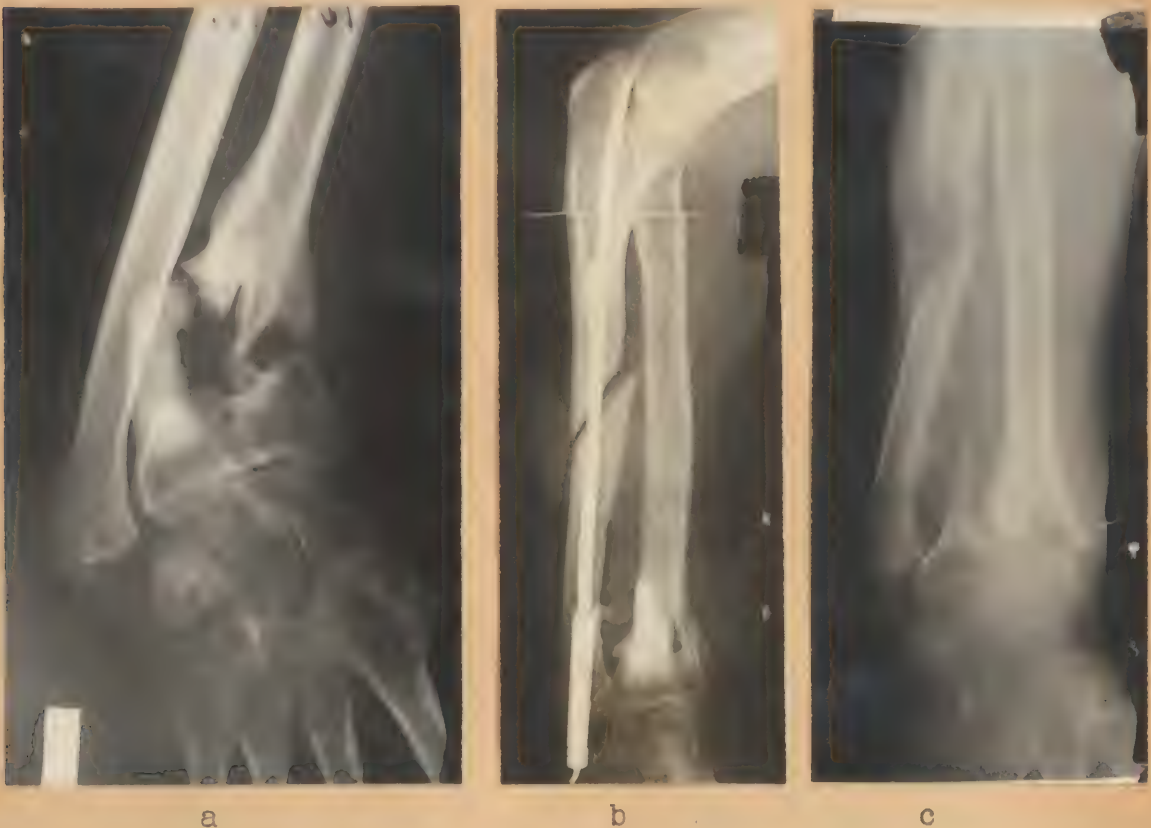


Illustration 187.

Pseudarthrosis of the radius near the wrist after shell splinter injury, 2 years old, of the 21 year old patient J.B.

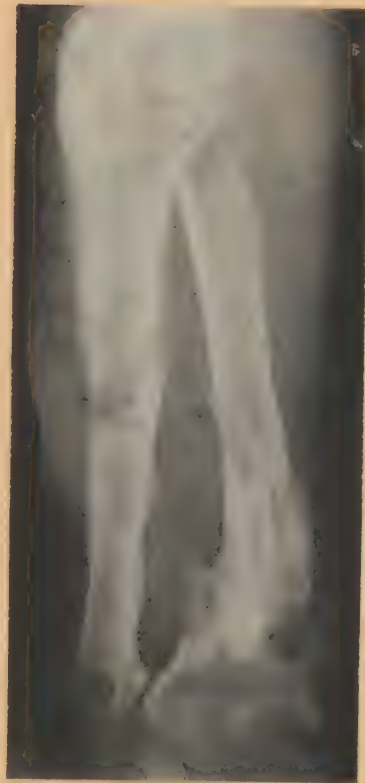
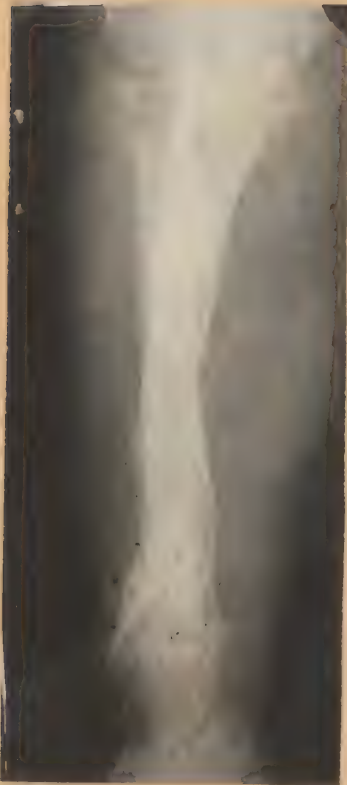
- a) before the operation
- b) after marrow nail shortening-osteotomy of the ulna by 3 cm. Method # 4. The tip of the nail endangers the elbow-joint. (The white line is an artefact caused by the X-ray film having been torn;
- c) for this reason, the nail has been removed, and an additional pseudarthrosis has now developed at the resection site of the ulna.



a

Thereupon, a piece of the radius was resected in the middle and both bones were nailed which made both pseudarthroses heal completely. The nails were removed 12 months after the first operation (see illustration 188).

The 28 year old patient H.H. had also a pseudarthrosis of the radius after shell splinter injury located far to the distal end. The pseudarthrosis was extensively splintered with a chisel and firmly united by resection of the ulna amounting to 3 cm. Thus, the present manus vara was also corrected. The pseudarthrosis healed firmly by bone (see illustration 189).

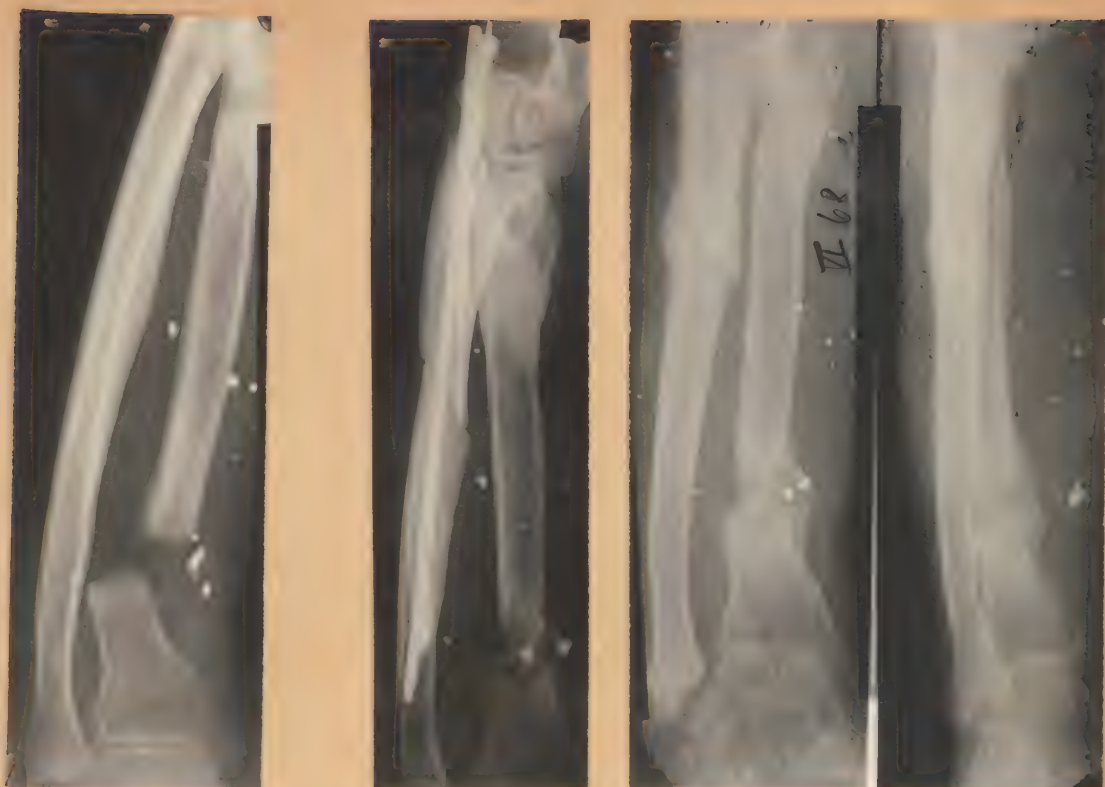


b

Illustration 188.

The same case as represented in illustration 187. Both pseudarthroses were healed by one more resection of both bones.

- a) after the second marrow nailing
- b) after removal of the nails, 12 months after the first operation.



a

b

c

Illustration 189.

Distally located pseudarthrosis of the radius after shell splinter injury; 28 year old patient H. H.

- a) before the operation
- b) after marrow nailing osteotomy shortening the ulna by 3 cm. and splintering of the pseudarthrosis.
- c) after extraction of the nail after 5 months.

The last example of a very distally located pseudarthrosis is the case of the 22 year old patient B.H. The pseudarthrosis had existed for $1\frac{1}{4}$ year and caused considerable complaints. It was nailed in a fistulating condition, and ring-sequestra appeared at the places of resection (see chapter IV). Nevertheless, the pseudarthrosis became firm by bone.

The nail moved into the elbow-joint. Thereupon it was drawn back. No infection of the joint developed. This is certainly the best proof that the infection does not at all, or at least not very quickly run along the nail, if the pus is not under pressure and if the nail is firm enough.

In the majority of these pseudarthroses, a considerable stiffening of the joints of the forearm existed, owing to the preceding long fixation in plaster cast or splint before the marrow nailing. In most cases, marked improvement could be

obtained due to the possibility of early motion after marrow nailing. Even in the cases with infection, no marked reduction of mobility because of the operation could be observed.

In one case, a complete stiffening of the formerly only half-stiffened elbow-joint occurred, but it can be regarded as a consequence of the resection of the radius head, and the marrow nail cannot be made responsible for it.

It was a pseudarthrosis of the radius at the border of the proximal third, which had been operated several times without any success. Movements of pronation and supination were possible only in the form of shaking movements. Flexion and extension in the elbow-joint were reduced to about 50 %. The pseudarthrosis had developed after a shell splinter injury and was 1 year old. The radius head was resected in the typical way (see chapter IX). The radius was nailed subsequently. An infection of the osteotomy site developed, which spread to the resection site and thus to the joint. The infection took a mild course, but caused a complete stiffening of the joint. For this reason, the resection of the radius head should, if possible not be temporally combined with marrow nailing, but an interval of about half a year should be allowed until the marrow cavity of the radius is safely separated by bone from the elbow-joint.

In peacetime surgery, where the danger of infection is not so important, it is, of course, quite possible to combine marrow nailing with bone grafting according to LEXER or with the spongiosa transplantation according to MATTI, as ZENKER has done. In a similar way as described with the lengthening osteotomy of the femur H. REICH placed a piece of the fibula on the marrow nail with a defect pseudarthrosis of the forearm and was successful, though it is generally not advisable to use this method with the forearm. The rotation strain of the osteotomy site is enormous and the difficulty of rendering the osteotomy site rotation-proof is considerably increased by bone-grafting. For this reason, it should be considered only in exceptional cases with very large defects. This is done safest with transplantation under the abdominal skin, as described earlier. But this procedure takes much time and is inconvenient to the patient. Absolutely certain and most simple at the same time is the described shortening-osteotomy with marrow nail union in the sound bone.

F. Marrow nail osteotomy with deformities.

1. The subtrochanteric osteotomy.

In case of congenital dislocations of the hip-joint, the indication for this operation is most frequently present. This operation corrects the existing abduction contraction and thus the seeming shortening of the leg as well. In addition, by obtaining a position of abduction, a shift of the total muscular pressure in the direction of the articular

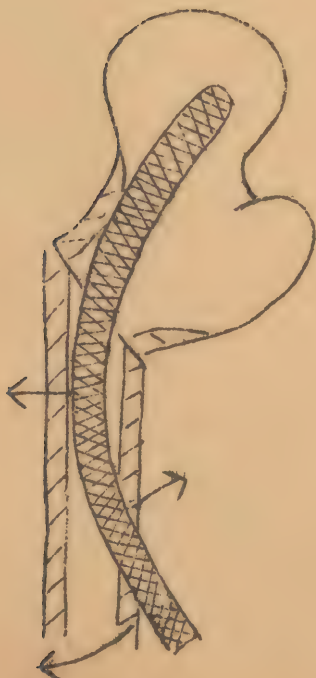
socket is obtained, which corrects or even removes the tendency of a dislocation from the articular socket. The operation corrects at the same time, the usually existing flexion contraction of the hip.

Another more rare indication is a hip stiffened by bone in an unfavorable position. At least, the PAUWEL operation, which has been described already in chapter III, must be mentioned. Its objective is to turn the unfavorable vertical fracture cleft of the femur neck pseudarthrosis into a more favorable one. Several suggestions of performing the section have been made. The technique of SCHANZ and the bifurcation according to LORENZ are best known. The hazard of the previous methods is the slipping off of the bone ends, which may cause disagreeable pseudarthroses. This hazard may be safely avoided by using marrow nails.

There are two methods of marrow nailing: the subtrochanteric osteotomy with the bent marrow nail according to the author and that with an angular marrow nail according to GUETTNER. The bent nail permits a very "stable osteosynthesis", since it is held by longitudinal-elastic forces. The nail is uniformly bent and broader at its head than at its point. The point is flattened at the concave side of the nail. The ordinary straight marrow nail is held by elastic forces working transversely to its longitudinal axis. The bent marrow nail touches the bone at 4 points, and, after firm driving in, is elastically fixed by its slight extension, thus extending the bone as well. This is schematically demonstrated in illustration 190.



a



b

Illustration 190.

Diagram of the fixation of the marrow nail by elastic forces.

- a) with the straight marrow nail, the bending of the transverse section is compressed;
- b) with the bent nail, bending in its longitudinal direction.

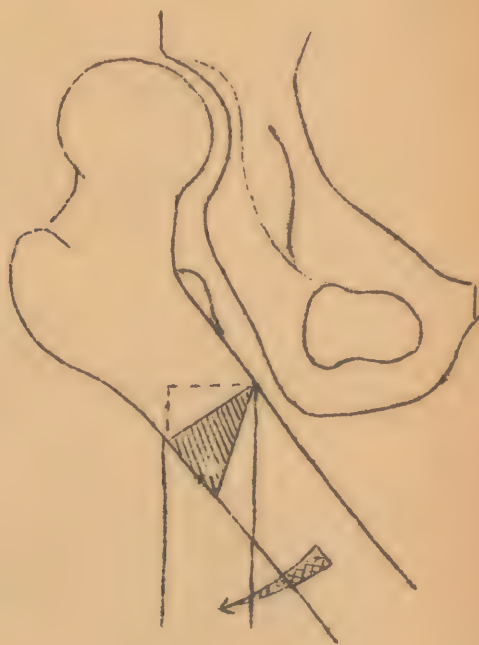
The technique of the subtrochanteric osteotomy then is as follows: The patient is laid on the side of the sound leg with moderately flexed hips. An incision of the skin is made which extends from the tip of the trochanter major to about below the trochanter minor, so that the place where the nail is driven in and osteotomy site are united in one wound. Then, as usual during SCHANZ's osteotomy, the bone is cut about 2 cm. below the trochanter minor and an exactly calculated wedge is cut out, the base of which is lateral and anterior. The size of this wedge depends on the size of the intended angle of correction. The wedge is measured best after an X-ray tracing. Then, a hole is drilled in the trochanter tip in the exact direction towards the osteotomy site with an awl and the nail is inserted in this hole, until its point appears in the osteotomy site. This point is then stuck in the distal bone fragment. Thereupon, the leg is extended and lifted and the nail is driven in finally. Then the skin is sutured and a drain left in place for 24 hours. The union is so stable, that the leg can be used a fortnight later. Marrow nails of various thickness and curvature must be available.

The method is now demonstrated by 3 examples:

The 16 year old S.S. had a congenital hip-luxation with dislocation of the articular socket and a marked adduction contracture. The operation was performed as described above, after an X-ray tracing had been made (see illustration 191).



191 a



191 b

After insertion of the nail, the intended position of abduction and extension was exactly established. The operation lasted 16 minutes. The healing course was without complications. The patient could get out of bed and walk after a fortnight. The TRENDLENBURG phenomenon was removed. The nail was extracted after 4 months. There was an excellent formation of callus. No atrophy of muscles or joint-stiffening occurred (see illustration 191)



c



d

Illustration 191.

- a) Congenital hip-luxation of the 16-year old patient S. S.
- b) Two X-rays laid on each other for measuring the size of the bone wedge which is to be cut out.
- c) after subtrochanteric osteotomy and nailing with a bent marrow nail. Contractions of abduction and angulation are corrected.
- d) after extraction of the nail after 16 weeks.

Illustration 192 shows an example of the use of a bent nail with a hip stiffened in adduction after infected arthritis of the 32 year old patient H.A.



Illustration 192.

Subtrochanteric osteotomy of the hip-joint stiffened in adduction.

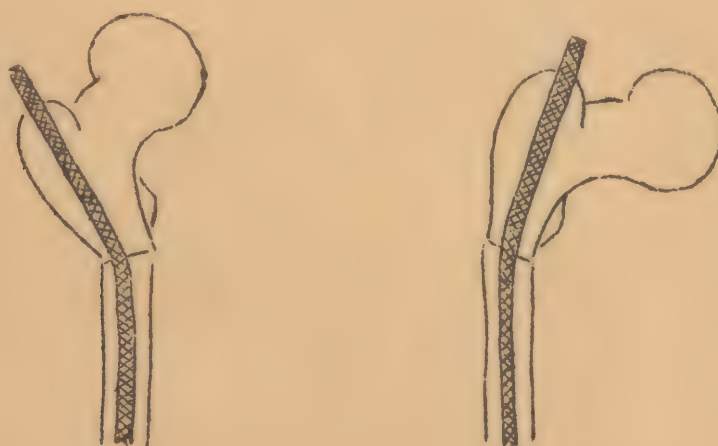
At last we demonstrate the application of Pauwel's operation, using the marrow nail:

It was a 2 year old pseudarthrosis of the femur neck, with which an unsuccessful attempt at nailing the femur neck had been made before. It was a medial fracture. The patient was 37 years old. With pseudarthroses like that the best results are obtained with the Smith-Petersen nail. In this case, however, there existed a considerable adduction contracture during the operation so that the subtrochanteric osteotomy in the sense of Pauwel's operation appeared indicated. The operation could be easily performed; though the patient was very fat, the operation lasted about 12 minutes only. The osteotomy healed without complications, but the pseudarthrosis did not, because the fracture slipped off. So an additional nailing of the femur neck was made, healing subsequently set in.

The subtrochanteric osteotomy with an angular nail.

Guettner proceeds in the following way: In the usual way, a guide rod is introduced under X-ray control and a thin marrow nail is driven in over it. Then, the femur is exposed from the outside and cut with a Gigli-saw. Then, a corresponding wedge is sawed out in front and at the outside, and the leg is bent forwards and outwards, which makes the nail bend as well. Then, a drain is inserted and the wound is closed in layers. The leg is now fixed in a Braun's splint. Four weeks later the patient can get out of bed without any additional plaster cast. Even in this form, the method saves the additional plaster cast.

REICH proceeded in case of contractions of adduction and abduction of the hip by calculating the angulation previously. Then, he bent straight strong femur nails in a vise to the corresponding angulation. Then, the wedge was removed and these nails driven in in the usual way. Thereupon, the leg adjusted itself automatically to the desired angulation, i.e. the leg raised when the adduction contraction was removed, as the patient lay on his side (illustration 193).



a

b

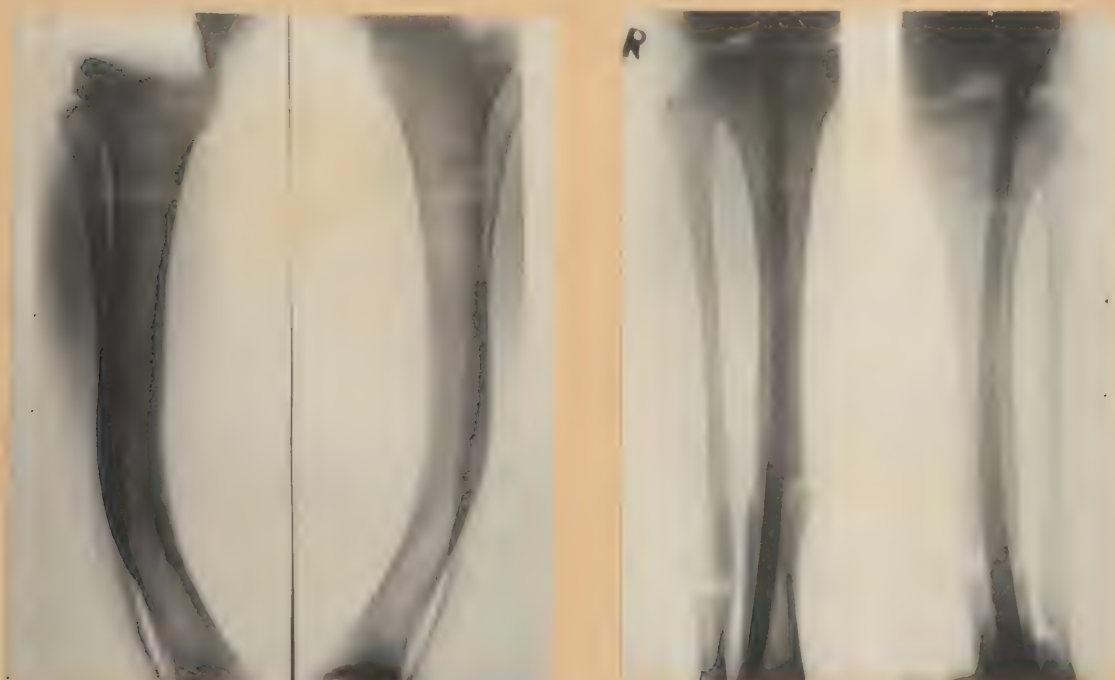
Illustration 193.

Angular nails to correct
a) adduction
b) abduction contraction.

These pictures have been kindly made available to us by B. REICH (Only sketches could be made).

2. Marrow nail osteotomy with bandy legs and knock-knee.

The use of the method with traumatic bandy legs and knock-knees has been described in the preceding section. Almost all of them are sharp angulations, which can be ideally treated with marrow nails. The non-traumatic deformities, which are in most cases of rachitic origin, may be either similar angulations or bends in which the whole bone is more or less involved. Also in case of very old fractures, the deformity gradually changes into the form of a bend. Since either the whole marrow cavity or greater sections of it are curved, it is difficult to use marrow nails. Thus, the first correction of bandy leg on the lower leg of a 24 year old man, that was performed by the author and GUENTZ was a failure. A wedge had been sawed out of the place of the sharpest curve, so that the bone ends faced one another in the form of a transverse section. After a synthesis had been attempted, with a tibia nail, the old curve reappeared. In one plane, the lower leg nail is flexible, so that it is possible to insert it in the bone. With this plane, the nail shifted by rotation to the direction of the old curve and assumed this curve so that, after insertion of the nail, the lower leg again had the same form as before the operation. Later, the author avoided this rotation dur-



a

b

Illustration 194.

Very curved rachitic bandy legs of the 18 year old patient S. H.

a) before marrow nailing

b) afterwards, both legs are completely straight.

ing the wedge-resection of the lower leg by driving in both nails at the same time. Herein he carefully saw to it, that the nails fitted well into the transverse section and were inserted so firmly that they could not rotate. Furthermore, the wedge was sawed out in a way that an oblique union-plane was formed. Thus, it was possible to permit the patients to get out of bed early without any plaster cast.

As an example we mention the 18 year old patient S.H. She had markedly curved lower legs in the form of bandy legs. The cause had been rachitis (see illustration 194).

The wedge had been so calculated that the existing inner rotation of the ankle joints was corrected as well. No plaster cast was applied. Both legs lengthened by 7 cm. each as a result of the straightening.

According to the author, failures can also be avoided by the use of Helferich's principle of oblique cutting, and we remind the reader of illustration 149, which shows the correction of a curvature of an old fracture, which is as flat as a rachitic deformity. In case of highly marked curvations, it is possible, too, in this way, to cut the bone at 2 different places with the counterincision saw.

After correction of a bandy leg of a 19 year old girl, E. GUENTZ observed a slipping off in the plaster cast despite V-shaped osteotomy according to ROEPKE, so he decided to perform a late marrow nailing. He used, however, only a broad, flexible lower leg nail and then bent the leg with the nail over a wooden wedge according to the procedure of MAATZ in case of late corrections of fractures. This is demonstrated schematically in illustration 195.

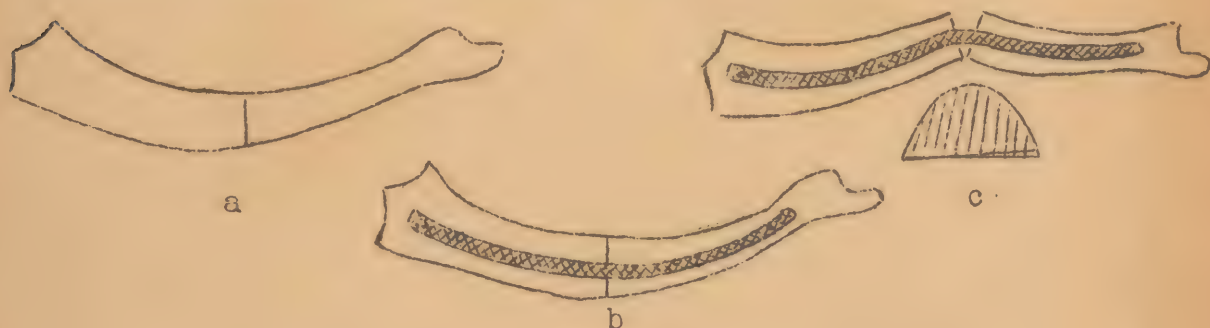


Illustration 195.

Diagram of the correction of a bandy leg by bending the nailed leg over a wooden wedge.

- a) before the marrow nailing
- b) after nailing with a flexible nail
- c) after bending.

Of course, an additional plaster cast must be applied to such a leg, but it is possible to remove it much earlier than without marrow nailing. Thus exercise of movement can be started earlier and there need be no apprehension that a lateral dislocation might occur.

To avoid a slipping off, GUENTZ recommends marrow nailing also during the supracondylar osteotomy.

3. Supracondylar osteotomy by means of marrow nails.

We do not speak of those cases in which in childhood only a chisel-blow was done and the leg bent then in the nature of the described HOFFA's osteotomy, because of bandy leg or turned-in legs or flexion contractions. These cases heal excellently in a plaster cast nor is the movability of the knee-joint endangered with children. This is not true for the knees of adult persons, particularly if an operation is performed so close to the joint. Frequently, however, rotation deformities must be corrected at the same time. Then, the bone must be completely cut and there is the hazard of a slipping off, particularly with older children and adults. By soft part contraction of these musculi gastrocnemii, the distal femur end glides off backwards. Whoever does not mean to correct the rotation fault does not so easily experience this inconvenience. The marrow nail can prevent it with certainty. The nail is not much supported in the spongiosa, but always lies eccentrically and is pressed against the compacta by the muscles so that it is rather well fixed. But this cannot be regarded as a "stable osteosynthesis" and an additional plaster cast is necessary also here, perhaps only in the form of a plaster sleeve. Even in this case, the advantage is that the cast can be removed early, as with the supracondylar osteotomy a long period of fixation is usually necessary because of the hazard of a refracture at this place.

We mention some examples of GUENTZ for the demonstration of this procedure: 18 year old girl, right leg in valgus position. On 15 October 1942, supracondylar osteotomy. After sticking them into each other, the fragments were well fixed but elastic. Plaster cast without including the pelvis. Even on 5 November, the plaster cast was reduced to a splint and movements of the knee-joint were started. On 19 November the patient got out of bed with a removable plaster sleeve, so that she could continue to exercise the knee-joint. On 1 December, no plaster sleeve and discharge from the hospital. On 11 January 1943, the nail was extracted. The ability to bend the knee-joint returned soon, but was still reduced for some months in its final motion, as a consequence of the aggravation of the gliding mechanism of the m. quadriceps caused by the formation of callus. As is well-known, this is an important reason why the formidable stiffening of extension of the knee-joint occurs after supracondylar osteotomies and fractures. To prevent that, early active motion of the joint is the most important remedy, but it is possibly only by fixation by marrow nails. GUENTZ ventured these exercises even after 3 weeks, in one case previously treated in the same way only after 5 weeks with the result that mobilization was associated with considerable difficulties. Further experience must show whether a simple plaster sleeve is sufficient and whether patellar motion may then be started at once (see illustration 196).



In the case of a 17 year old boy, the fixation by a nail during a supracondylar osteotomy because of flexion-contracture of the knee-joint owing to paresis of the quadriceps brought a considerable relief. The fragment sat firm at once, so that, without any regard to the osteotomy, the plastics of the quadriceps could be made out of biceps and sartorius and, after 5 weeks, exercise could be started without plaster cast (see illustration 197).

Illustration 196.

Supracondylar osteotomy in an 18 year old girl because of valgus position of leg. Impaling of the distal fragment. Even after $3\frac{1}{2}$ weeks, beginning with movements of the knee-joint according to E. GUENTZ.

With a seven year old girl with turned-in leg position the highest degree and dislocation of the axes because of a congenital fibula defect, the osteotomy slipped off in plaster and could be held only by a second opening of the operative site and impaling by a marrow nail. Extensive contractures of position like that should be operated accordingly on principle even in small children.

If the knee-joint is completely stiffened, one can, with use of a nail slowly passing through the knee, obtain a completely "stable osteosynthesis", which requires no plaster cast and permits the patient to get up a few days after the operation. We mention some examples of GUENTZ.



Illustration 197.

Supracondylar osteotomy because of flexion contraction of the knee-joint owing to paresis of the quadriceps combined with plastics of the quadriceps. Start of motion 5 weeks after marrow nailing.

Fifteen year old boy. At the age of 10, resection of the knee-joint because of incomplete stiffness of the joint after empyema. Despite (or because of the now too small?) knee-shell, formation of an increasing flexion position with loosening of the femur epiphysis as seen in the X-ray. Flexion position 135 degrees. On 28 June 1943, osteotomy with insertion of a 55 cm. long nail. In the lower leg, it lay involuntarily somewhat eccentric, so it pierced the corticallis below the condyles and lay along the outside of the tibia wall. Complete fixation all the same. No plaster cast. On 12 July 1943 getting out of bed, on 23 July 1943 discharge with a precautionary plaster-sleeve, since the boy did by no means spare the leg and was glad to be able to use it properly now.

With a 14 year old girl; too (illustration 198), who had to be operated for the same reason with a simultaneous correction of the position of rotation, no plaster cast was necessary, and the patient was able to walk $2\frac{1}{2}$ weeks later.

4. Marrow nailing of foot deformities.

With foot deformities the method has been used comparatively seldom so far.

GUENTZ reports about the following case:

A 20 year old female patient with a left-club-foot, which had been operated several times before and was now completely crippled. The considerably shortened posterior foot was stiff, the fore-foot was markedly supinated, the large toe was angulated at a right angle to support the first metatarsal as in case of a hammer-toe flat-foot. There were numerous

pressure callosities on the lateral edge of the foot and on the dorsum of the large toe. Amputation was suggested, but refused by the patient. The objective of the operation was to turn the first metatarsal down as a support without any greater intervention which would have deformed the foot even more. First, $2/3$ resection of the base joint of the large toe according to BRANDT, then osteotomy of the first and



Illustration 198.

Supracondylar osteotomy on a completely stiff knee-joint. 55 cm. long marrow nail. Patient: 14 year old girl. No plaster cast. Complete ability to walk after $2\frac{1}{2}$ weeks.

second metatarsals at the base. In order to fix the position of the first metatarsal, a small marrow nail is driven in from the metatarsal head to the middle of the foot, without any respect to the small joints, but, as a precautionary means, an additional plaster cast treatment was carried out. Surprisingly the large toe was quite movable after 7 weeks, though the end of the nail protruded somewhat from the metatarsal head. This was an attempt started owing to the peculiarity of the conditions. Its success affords justified hope for using marrow nails during forefoot operations of hollow and spraddling feet and similar deformities (see illustration 199).



Illustration 199.

Osteotomy on the first metatarsal of a 20 year old girl. Correction of an old club-foot with raised first metatarsal and hammer toe according to E. GUENTZ.

G. Marrow nailing in case of bone tumors.

Prophylactic marrow nailing.

1. Marrow nailing of non-malignant tumors.

Considering the facts described in this chapter, marrow nailing suggests itself after resection of non-malignant tumors, and the method depends entirely on site and extent of the tumor and the affected bone. The technique of marrow nail osteotomy is then just the same as described in the sections on osteotomy and pseudarthroses. The same advantages are present also here. They result from the durability, firm union, and early movability. Even in 1940, the author nailed tumors. One case was a

six year old girl with a chondroma the size of an apple in the middle of the right upper arm, which was healed by continuity resection. In the second case, the 11 year old boy H.P. a chondroma existed too. The condroma was subtrochanterically located and had caused a spontaneous fracture. The boy had lain in plaster for 18 weeks, but no sign of healing of the fracture could be observed. The tumor was the size of a walnut. It was scraped out and a marrow nail inserted. Even 3 weeks later, the boy could get out of bed. The nail was removed after 6 months. The bone had healed. A late examination after 1½ years showed no symptoms of disease any more (see illustration 200).



a

b

c

Illustration 200.

Non-malignant tumor (chondroma) with spontaneous fracture of the 11 year old boy H.P.

- a) before marrow nailing
- b) after scraping out of the tumor and marrow nailing
- c) some time later, sufficient formation of callus.

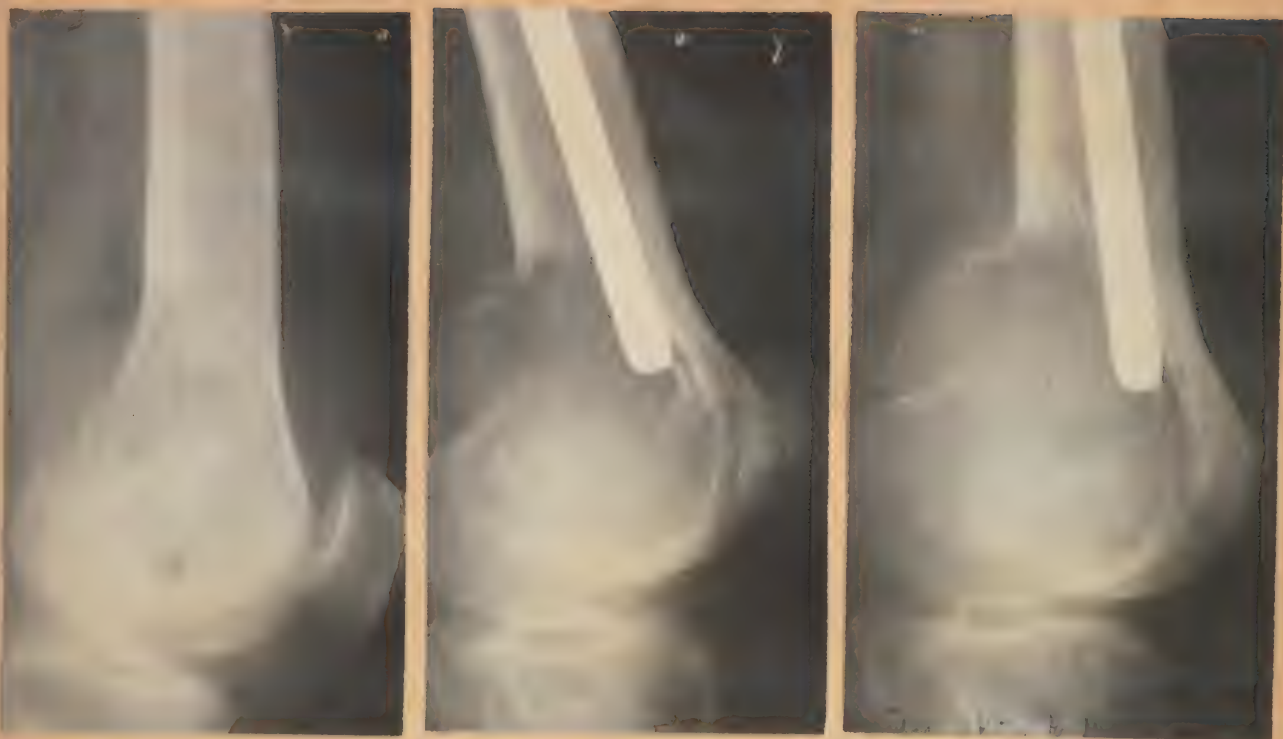
BOEHLER describes an interesting case of his clinics: It was an *ostitis fibrosa cystica localisata* of a 32 year old woman. The cyst was 7 cm. long and was located in the upper third of the left femur. The wall was as thin as paper. EIGENTHALER performed a closed marrow nailing. After introduction of the guide rod (chapter V), the bone broke after a slight turn. The fracture cleft ran obliquely across the cyst. Thereupon, the nail was driven in with-

out opening the cyst. The fracture caused a negligible shortening (6mm.). After the marrow nailing, the former tension pain had disappeared. After a fortnight, the patient could independently lift her leg from the bed, which had not been possible before the operation. After 5 weeks, she got out of bed and, after 6 weeks, she left the hospital without any complaints. After 8 months, the nail was removed under local anaesthesia. The cyst was no more recognizable in the X-ray. BOEHLER writes about this case:

"The course of this case is the best proof that the *ostitis fibrosa cystica localisata* is a disease of the bone caused by tension. By the insertion of the marrow nail, the cyst was opened and its contents could drain constantly. In contrast to a spontaneous fracture, the cavity wall could not close any more and so no new tension could develop. Since the pressure from the inside was absent, the bone formed without impediment. The healing was sped by the fracture caused by the drilling of the guide rod with opening of the cyst in the whole wall and by the slight shortening thus caused".

The otherwise usual therapy with scraping out of the cyst and implantation of a large bone graft is a major operation. On the other hand, closed marrow nailing is a short and simple intervention, if performed by a skilled surgeon. The fine pictures which BOEHLER adds to the description of this case are convincing. Further experience will show whether it is really possible in every case to make the *ostitis fibrosa localisata cystica* heal. At the suggestion of BOEHLER's case, the author made a closed marrow nailing with the same disease, though the case was less favorable, as a cyst the size of an apple in the femoral condyles was involved. Since the cyst was located far to the distal side, the draining path along the 42 cm. long nail was perhaps too long. It was the case of the 46 year old man K.P. who had suffered from complaints in the knee-joint for 1½ years. The roentgenogram showed a large cyst. A test excision was made first. The diagnosis was histologically confirmed by BUENGLER/Kiel. Also the closed marrow nailing was performed with the utmost care and a Volkmann's splint subsequently applied. The nail point stuck in the middle of the tumor. No success was obtained, however, but the cyst was at least the same size after 6 months as before the operation. But the pain disappeared after the marrow nailing. As a matter of fact, no marked formation of callus can be expected in the spongiosa of the femur. In BOEHLER's case, one can well observe the approach of callus from all the compacta directions. Maybe, this is the explanation of the failure (see illustration 201).

GRIESSMANN and SCHUETTEMEYER report about a brown tumor in the area of the trochanter minor of a 10 year old boy. The tumor had been discovered accidentally in the X-ray. One year later, a spontaneous fracture occurred at that place, following a minor trauma. No satisfactory position



a

b

c

Illustration 201.

Ostitis fibrosa cystica localisata
of the 46 year old patient K. P.
a) before the closed marrow nailing
b) 6 months afterwards
c) no success was obtained.

could be obtained with wire extension, etc. but a percutaneous marrow nailing without exposure of the fracture was successful. The fracture healed, and the nail could be removed even after 4 months.

2. Marrow nailing of malignant tumors.

Marrow nailing of malignant tumors is now performed to an increasing degree. It has a precise indication. Of course, no one will pretend that the nail impairs the growth of the tumor. Its therapeutic effect is only symptomatic. We can eliminate the symptom of a spontaneous fracture. This is a great deal. It is often the only symptom of a malignant bone tumor or a malignant bone metastasis. Then we can give the patients the illusions of being healthy again for a long time, but above all, it is possible to make the rest of their lives more comfortable. In the majority of the cases, the spontaneous fracture is located in the area of the trochanter minor. This was stated, for instance, by UDERSTADT at the suggestion of the author in a statistical synopsis of the clinics of Kiel. Why the bone tumors and the metastases of certain malignant tumors

have a predilection for that very place is absolutely obscure. That the capillaries at this place are said to have a certain width as nowhere else in the whole body and that the cells circulating in the blood are said to stick just there, is not easy to imagine - easier that the power of resistance of the bone tissue against the settling down of tumor cells is there less great, since the bone is at that place exposed to a particular strain. At that place, the author was able to ascertain the mentioned (chapter III) whirl of force-lines. Also this attempt of explanation appears to be quite strained. Anyhow, it is a fact that the tumors are located most frequently at that place and the patients have had to lie the last few years or months of their lives in a pelvic cast. This cast cannot be kept clean in the long run, however carefully it is applied. In addition, there is the hazard of a decubital ulcer, the weakening of the general condition by lying on the back, etc. and not least the mental suffering.

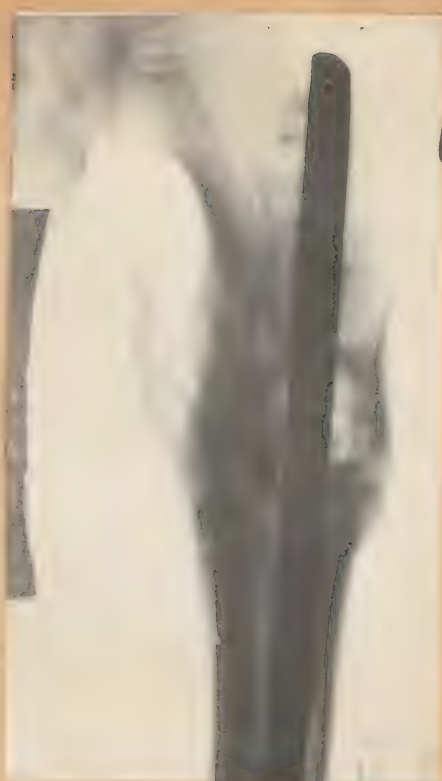
The marrow nail liberates one from all this, even in those cases where there is no hope that the cleft of the spontaneous fracture might be bridged over by callus. Experience has shown that the marrow nail can afford complete support to the bone, and we remember the patient of the author described in chapter II, who rode 18 km. every day on his bicycle after a femur osteotomy, though the fracture was not yet firm nor could be, since the operation had been performed only 3 weeks before. In this context, BOEHIER has pointed out those of his cases where he was able to show that people with nailed femur pseudarthroses are fully able for work, though the fracture is not firm at all.

Only inoperable tumors can be considered for marrow nailing; also those cases in which the patient refuses the suggested amputation, which occurs quite frequently. With many bone tumors, the therapeutic value of the amputation is doubtful anyhow, so one often proposes amputation only with reserve. The metastases of malignant tumors may also be an indication, since they are almost always inoperable. Only few exceptions are known in literature. Thus, W. ANSCHUETZ reports about 2 cases of bone metastases after the removal of a hypernephroma. In both cases, there was only one single metastasis and these were the only ones, after the removal of which the patients were regarded as healed for good. The intervention is usually performed in the form of closed marrow nailing. In some cases, however, one has to accept the exposure of the tumor, too. Then, a histological examination may be made to settle the diagnosis. This applies above all to tumors the nature of which remains obscure as regards clinical history, clinical examination and impression of the roentgenogram. Then, the technique of marrow nailing is the same as with osteotomies (see illustration 202).

Now the question is raised at once whether the nail fosters metastases considerably and thus shortens life. The nailing certainly seems to be an appropriate means to spread metastases artificially.



a



b

Illustration 202.

Example of the marrow nailing of a subtrochanteric metastasis of a carcinoma of the breast.

- a) before marrow nailing
- b) after marrow nailing

In many cases, one would risk even that to render an intolerable life tolerable again. Cases are known where such a spreading of metastases is distinctly recognizable in the X-ray. Thus, HAASE describes a case of subtrochanteric hypernephroma metastasis where, after marrow nailing, numerous inoculated tumors the size of peas are visible in the X-ray along the entire length of the nail. Here, the nail has carried away the tumor cells and dispersed them over the whole marrow cavity. Also a case of the clinics of Kiel shows a similar spreading of metastases. It was a metastasis the size of a hen's egg in the area of the trochanter, after a bronchial carcinoma. The female patient J.S. was 45 years old. A marrow nailing and intense radiation by X-rays were performed, and the metastasis completely disappeared. One year later, however, new metastases appeared distally in the marrow cavity along the nail and did not cause any complaints. Since the marrow nailing, the patient could walk without pain and is now receiving X-ray treatment again (see illustration 203).



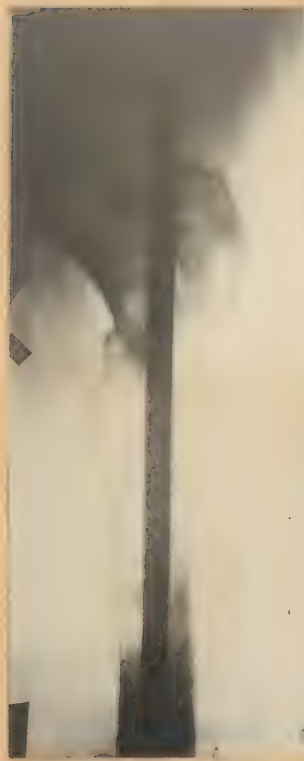
a



b



c



d

Illustration 203.

Metastasis of a bronchial carcinoma within the trochanteric area of the 45 year old female patient J.S.

- a) before marrow nailing
- b) after marrow nailing
- c) after 1 year
- d) after an intense X-ray treatment the primary metastasis disappeared, but new metastases were formed more distally along the nail. Since the marrow nailing, the patient has walked without complaints.

In the majority of the cases, however, this spread of metastases does not appear, and the 2 mentioned cases are exceptions. We now describe the case of R. WANKE, Kiel.

It was an operated breast carcinoma. The metastasis of the bone was localized in a similar way as in the preceding case. A spontaneous fracture occurred. Marrow nailing was performed with subsequent intense radiation. The metastasis disappeared. The patient could walk even shortly before her death, which occurred $1\frac{1}{2}$ years later on. She died of a relapse of her tumor. (See illustration 204).



a



b

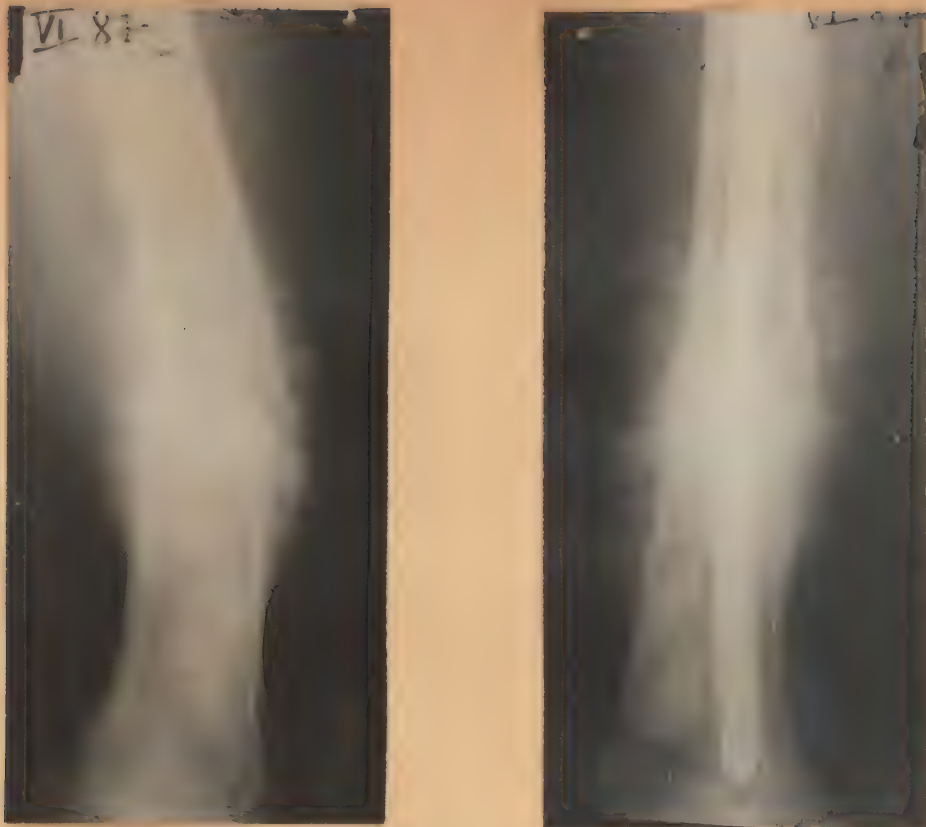
Illustration 204.

Metastasis of a breast carcinoma in the area of the trochanter.

- a) before marrow nailing
- b) after intense X-ray radiation, 1 year later (according to R. WANKE).

Even in 1940, the author nailed 2 osteoblastic bone sarcomae, in which spontaneous fractures had occurred. After the marrow nailing, both patients were again able to walk, but lived only for 4 and 5 months. Both died of pulmonary metastases, but had had pulmonary symptoms even at the time of the intervention. In one case, such a metastasis could even be proven with the X-ray (see illustration 205).

The problem is not yet decisively settled whether the nail actually causes a more marked spread of metastases. It can be judged, only by an extensive statistical study. The theoretical idea often does not correspond to practice. This is also true for the opinion that the prospect of healing is considerably decreased by biopsy excision from a malignant tumor. This is well imaginable theoretically, but cannot be proven statistically. Thus, a large statistical study of W. SIEMENS, Kiel, shows no influence of the biopsy excision on the healing prospects of breast carcinoma.



a

b

Illustration 205.

Osteoblastic sarcoma of the femur with spontaneous fracture. Thirty-five year old female patient M.E.

a) before marrow nailing

b) after marrow nailing

In such desolate cases, this question is of only subordinate importance, since it only purports how many weeks or months life is shortened by the intervention. The important thing is that marrow nailing can render life more satisfactory again.

One must finally admit a certain therapeutic influence of the marrow nail on the tumor. The constant small movements in a spontaneous fracture doubtless have some part in the bursting of lymph-paths, tearing of vessels of a tumor rich in vessels and the pressing of tumor masses into clefts of the tissue. We can eliminate these movements, not with a plaster cast, but certainly with a marrow nail. The general condition is much easier to improve, if the patients can get out of bed than if they lie in bed with a pelvic plaster cast. Finally, the marrow nail facilitates the X-ray radiation. The single radiation is easier since the patient can be laid in whatever position one chooses, and he may be radiated from more planes than in a plaster cast. If the nail is hit by X-rays it emits a strong secondary radiation, which might be of therapeutic value.

In some cases, the tumor in the area of the trochanter can be fixed better with a Y-shaped nail than with a straight nail (see chapter V).

3. Prophylactic marrow nailing.

In some of the described cases of bone tumors, the spontaneous fracture had not yet occurred, but a marrow nail should be inserted, because the fracture was imminent. Such a prophylactic marrow nailing saves the patient much pain, distress and other disadvantages. In most cases, the tumor is recognized previously by drawing pain, etc. Sometimes, it is also discovered as an accidental finding during an X-ray examination. If the indication of inoperability mentioned with the malignant tumor or if the patient refuses amputation, one will usually not hesitate to perform the prophylactic marrow nailing. In addition, it is technically easier if the spontaneous fracture has not yet appeared. The majority of the patients agree at once with the proposal if the consequences of further waiting are described to them. A patient of the clinics of Kiel refused at first and went home. Eight days later, he returned and had the nail inserted. In the meantime he did not get any sleep for fear to awake with a broken leg in the morning, which had been predicted to him as possible.

Such a prophylactic marrow nailing may be finally considered also in case of a osteogenesis imperfecta. Frequent fractures occur though they all heal rapidly. The final result of the numerous fractures, however, are often considerable deformities. In addition, the patients are hospitalized a long time etc. Here, the nail can prevent further fractures. As an example, we mention the 9 year old G.M. who had broken the left femur 7 times, the right femur 6 times, and that always subtrochanterically. Illustration 206 shows this case after prophylactic marrow nailing. The right nail was inserted 2 years ago, the left one year ago. After marrow nailing, no more fractures occurred (see illustration 206).



Illustration 206.

Prophylactic marrow nailing in case of osteogenesis imperfecta of the 9 year old G.M. Before the marrow nailing, the right femur had been broken 6 times, the left 7 times. The right nail was inserted 2 years before, the left 1 year. Since then, no more fractures.

Considering the rapid growth in childhood, it is important to check the position of the nail in the X-ray at intervals of $\frac{1}{2}$ year, lest it disappears under the trochanter tip (see chapter V). Then, it must be replaced in due time by a new one. This is a small operation (see chapter V).

H. Osteotomy statistics.

In conclusion of the chapter on osteotomy, we mention 2 statistical tables, which clearly show what an eminent remedy we possess in the marrow nail for the osteosynthesis. Not all the advantages of early movability, the anatomical final result obtained and the degree of restoration of the function are listed therein, but only the question is roughly answered: Was any success of the osteosynthesis - i.e. union by bone - obtained or not?

The following table was compiled by KOENIG and WIRTH. It was made from a compilation of 103,314 fractures at 59 hospitals.

TABLE OF THE METHODS OF OSTEOSYNTHESIS AND THEIR FAILURES. (according to KOENIG and WIRTH).

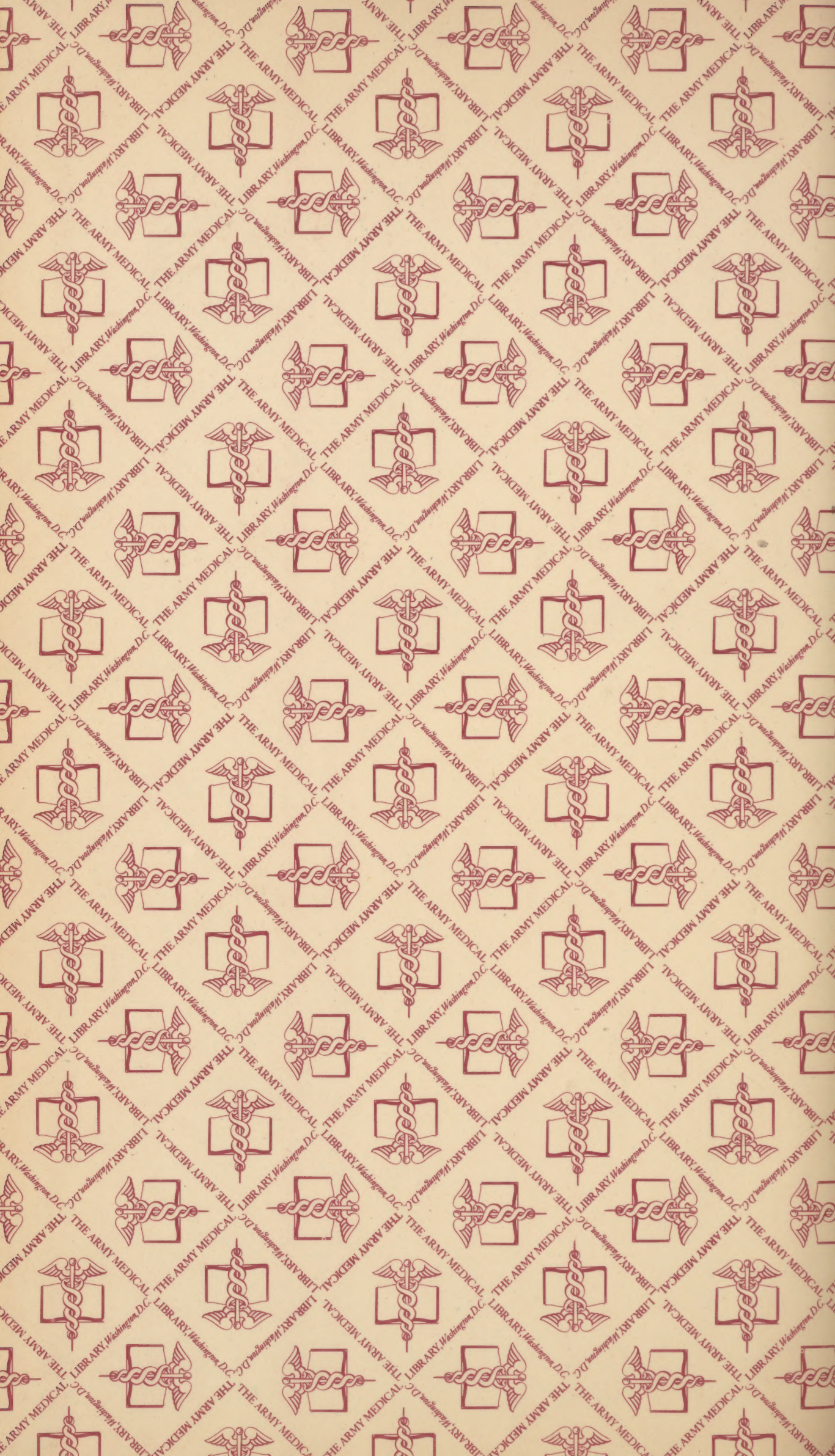
Method	total # of cases	failures	per- centage
Simple wire suture after operative exposure	38	12	31.6
step-like freshening with wire suture	45	4	8.9
Kirschner's splintering	68	10	14.4
simple bone grafts	214	40	18.7
bone grafts with wire suture	22	5	22.7
osteoplastic bolting	38	5	13.2
autoplastic transplantation of spongiosa	17	1	5.9
autoplastic bone bolting	30	7	23.3
ivory bolting	26	6	23.1
Lane's plate	14	3	21.4

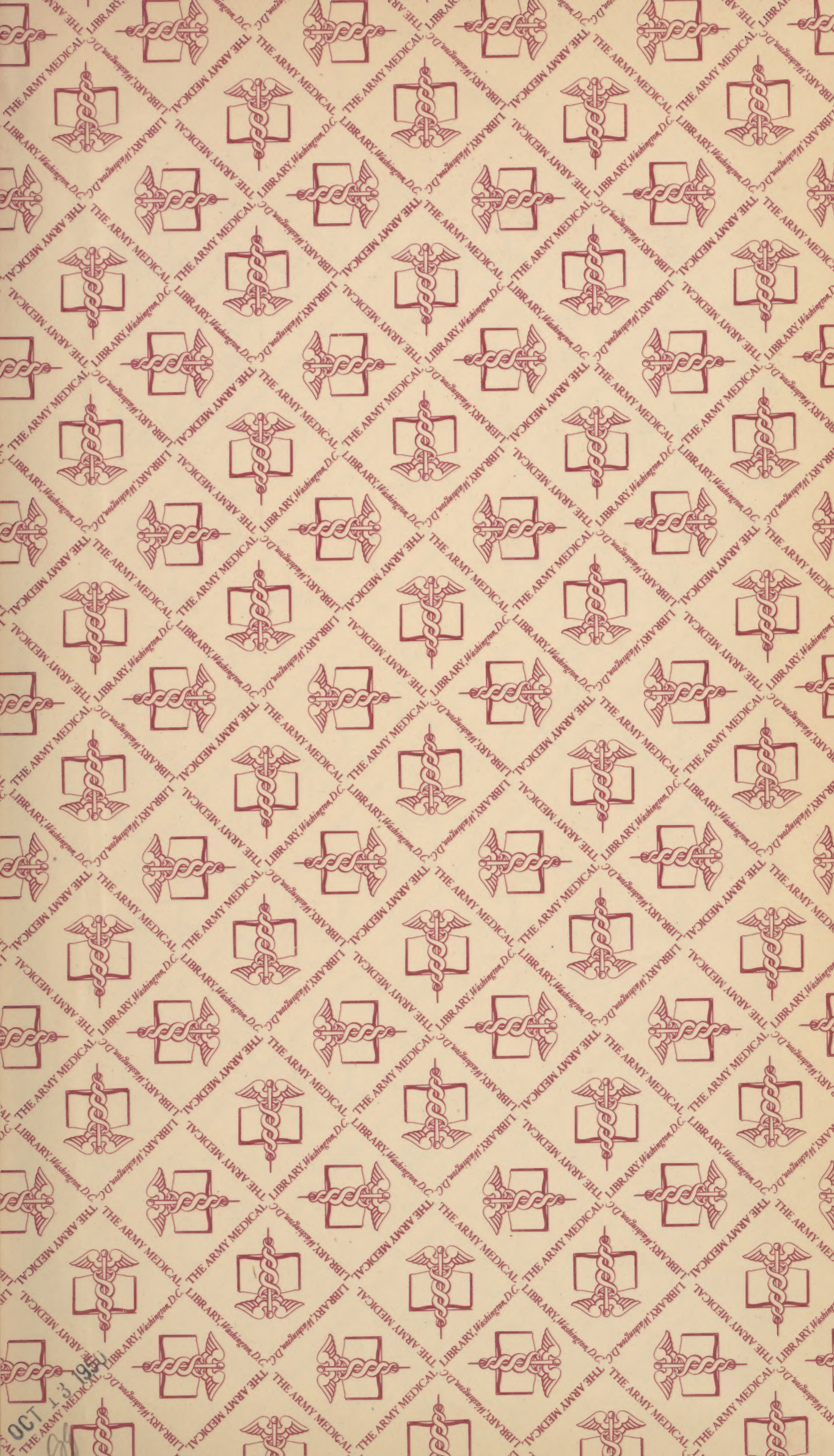
In comparison to this, marrow nailing:

Osteosynthesis by means of marrow nails after osteotomy	total # of cases	failures	per- centage
Patients of KUENTSCHER	287	2	0.7
patients of the clinics in Kiel	not available		
patients of HAEBLER	not available		
TOTAL:	287	2	0.7

No closed marrow nailings are included in order to be able to compare them under approximately equal conditions. If they were included, the figures would speak even more in favor of marrow nailing, since the healing conditions are much better with them. As regards the figures of the author, one must consider that numerous serious pseudarthroses are included. The absence of a number of failures worth mentioning after marrow nailing is eventually also experimental evidence, as it were, for the correctness of the mechanico-biological theories developed in chapter III.

The failures among the patients of the author are the pseudarthroses of the forearm, represented in illustration 176 and 177, which were healed after a second marrow nail osteotomy.





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